Glazing of Salmon on Freezer Vessels

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ABSTRACT

Gibbard, G.A. and E.G. Baker. 1984. Glazing of salmon on freezer vessels. Can. Tech. Rep. Fish. Aquat. Sci. 1271: 55 p.

The amount of glaze picked up by a frozen fish in a dipping process depends on a number of factors such as:

fish weight
fish temperature
glaze water temperature
dip time and number of dips
fish shape and configuration.

In addition, the fish lose glaze by sublimation in cold storage.

A number of experiments were made to investigate the effect of each of these variables when glazing Pacific salmon under conditions typically experienced on freezer vessels at sea. A similar study was made using small farm raised chinook salmon. The results are presented in a number of graphs showing the variation of the percentage glaze with the fish weight for each of the temperature and dip-time conditions used. Other factors are also compared. An empirical relationship between glaze percentage and thickness is developed to make it possible to establish glazing procedures for the particular conditions of any freezer vessel that will ensure that each fish will be covered with an adequate glaze thickness (1 mm minimum) to protect it from quality deterioration in subsequent freezer storage. Recommendations are also given on all aspects of glazing and storing frozen salmon on the vessels.

Key words - glazing, salmon, freezer vessels, frozen storage.

RÉSUMÉ

Gibbard, G.A. et E.G. Baker. 1984. Glaçage du saumon à bord de bateaux congélateurs. Can. Tech. Rep. Fish. Aquat. Sci. 1271: 55 p.

La quantité de glaçage adhérent au poisson congelé durant le procédé de la trempée dépend d'un certain nombre de facteurs, tels que:

le poids du poisson
la température du poisson
la température de l'eau de la trempée
la durée et le nombre de trempées
la forme et la configuration du poisson.

En plus, le poisson perd du glaçage du à la sublimation durant l'entreposage à froid.

On a fait un certain nombre d'expériences pour étudier les effects de chacun de ces facteurs lors du glaçage du saumon du Pacifique dans des conditions typiques observées sur les bateaux congélateurs en mer. Une étude semblable a été faite en employant des petits saumons chinook d'élevage. Les résultats sont présentés sous forme de graphiques montrant les variations des pourcentages de glaçage avec le poids du poisson pour chacune des températures et des durées de la trempé employées. On a également comparé d'autre facteurs. On a developpé un rapport empirique entre le pourcentage et l'épaisseur du glaçage afin de pouvoir établir des procédés de glaçage pour les conditions particulières à n'importe quel bateau congélateur. Cela permettrait d'assurer que chaque poisson soit recouvert d'une couche de glaçage d'épaisseur adéquate (1 mm minimum) afin d'empêcher la détérioration de la qualité au cours de l'entreposage congelé subsequent. On donne également des recommendations sur tous les aspects du glaçage et de l'entreposage du saumon congelé sur les bateaux.

Mots-clés: glaçage, saumon, bateau congélateurs, entreposage congelé.

INTRODUCTION

Glazing of frozen whole dressed salmon has been employed routinely for many years on B.C. freezer vessels to protect the fish from dehydration, oxidation and denaturation. The glaze is applied by dipping the frozen fish individually in chilled water for a short time and then allowing a thin layer of ice to solidify on the surface. For the most part this has been done in an uncontrolled way and there have been many problems with too little or too much glaze reported by the buyers and inspectors. A recent sampling of 138 fish from freezer boat landings taken by the Department of Fisheries Inspection Branch (Schallie, 1979) showed glaze amounts varying from 0 to 16 percent with half of the fish having less than 5 percent. Glaze is usually defined as the percentage of ice added to the fish (weight of ice/weight of fish x 100%) and about a 5 percent glaze has been considered by the industry to be adequate to protect the fish (Davies, 1980) but the actual amount of glaze a fish will pick up depends on a number of factors:

fish weight
fish temperature
glaze water temperature
dip time and number of dips
fish configuration - head-on, head-off
fish species, shape, etc.

Gora et al. (1972), Zvereva et al. (1977) and Graham (1981) identified the key variables determining the amount of ice picked up during glazing and reported some experimental results for glazing of individual fillets or blocks of fillets or of whole gutted fish. Zaitsev (1962) and Pottinger and Miyauchi (1963) describe glazing procedures primarily as used in processing plants ashore and also discuss recommended values of some of the variables for glazing unspecified individual whole fish but give little experimental data of the amount of glaze picked up under any particular condition. Bedford (1941) described a process for ice glazing coho salmon and Amasaki (1940) reported glazing results for individual salmon weighing 2 to 2.3 kg. The thickness of glaze obtained is given for dip times up to 5 min for one set of conditions, fish temperature -12°C and water temperature 0°C. As well

as these variables the fish lose glaze at a steady rate by sublimation in the freezer hold of the vessels with the total amount lost by each fish depending on the time it has been stored and the conditions of storage which may vary from place to place in the fishhold. Lemon (1932) reviewed the causes of loss of glaze in cold storage, the relationship of shape and size and methods for preventing evaporation. He also presented some experimental results showing up to 16 percent ice-glaze loss from bluefish, sea trout and butterfish under cold storage conditions of that time. Young (1932) reported an ice-glaze loss of 2.4% from salmon and 2.5% from halibut stored for 12 weeks in a commercial cold storage room.

This report gives the results of a number of experiments performed in order to determine the influence of each of the factors and the effects that various glazing procedures commonly practiced on the freezer vessels and on the unloading docks can have on the fish. Also included are data for the glazing of small salmon produced in fish farms.

METHODS AND MATERIALS

Fresh Pacific salmon of all 5 species were collected primarily from chartered seiners fishing in lower Johnstone Strait in October 1981 and August 1982. A total of about 250 fish were used. The fish were gutted, thoroughly cleaned and washed and then frozen by either plate or air blast freezer using procedures and methods as practiced on freezer vessels. These fish were normally dressed, head-off, but for sockeye, dressed, head-on fish were also used as they are often landed in this condition for special markets. Approximately 40 small fish, primarily chinook salmon, were also obtained directly from a fish farm. These fish were dressed, head-on when received. Some of the fish were weighed and measured to determine physical parameters relevant to freezing and glazing. Thermocouples were inserted into sample fish before freezing to be used for temperature response studies and for the measurement of fish temperature during storage and when glazing. The fish were stored protected by plastic bags for a minimum of 18 hr after freezing to equilibrate at the storage temperature.

For glazing, a 20 gal. plastic tub was filled with the glazing mixture; normally half-strength sea water (1.5% salt) but also pure sea water (approx. 3% salt), fresh water or sea water with a 1 percent dextrose additive. The water was prechilled to the desired temperature in the cold room or by the use of ice. The freezer ante-room where the glazing took place was at a temperature of 0 to -4°C. Fish were taken individually from the cold stores, immediately weighed and then dipped in the glaze tank, vertically, head end down. After the desired length of time the fish was removed and held over the tank until all excess water dripped off (approx. 5 sec) and then reweighed. If double dipping was being done the procedure was repeated after the appropriate interval between dips. Normally 30 sec intervals were used but other times were also tried to determine their effect. The fish were then returned to the cold stores to harden the glaze and for subsequent storage studies or subjective examination of the glaze quality.

For most experiments the percentage glaze was determined for a range of fish sizes and at various dip times with all other factors being held as constant as possible at preselected values. It was not feasible to investigate a full range of all variables but a few representative examples of each were chosen as follows.

Fish temperatures -28°C, -25°C and -20.5°C

Schedule III of the Canadian Fish Inspection Regulations requires that fish shall not be removed from a freezer until its core temperature is -20°C or lower and that storage areas in which frozen fish is held on board a vessel must be maintained at -26°C or lower. The -20.5°C temperature was used in these experiments to determine the glaze that would be picked up on a fish immediately after removal from the freezer, the -28°C would be the temperature of fish allowed to equilibrate in a typical fish hold and -25°C would be for glazing at an intermediate stage of equilibration. Because of seasonal changes in cold storage temperatures during these tests, carried out over two years, the above values could have varied by ± 1 to 2°C for the experimental fish.

Water temperature -1°C, 1.8 to 2.5°C plus a range of values to 14°C

Davies, 1980; Gora et al., 1972) and other sources recommend that the glaze water be prechilled to 1 to 2°C and therefore a temperature of about 2°C was selected as one experimental point but, because it is usually located in the cold storage area on the vessels and is chilled by the frozen fish dipped in it, the water quickly cools down to its freezing point (-1°C for half-strength sea water) and it is likely that most fish are glazed at this temperature. Thus -1°C was also used as a test temperature in these experiments. It is also much easier to control the temperature of the water when it is at the freezing point with only occasional additions of small quantities of warm water required to prevent freeze-up. These values varied by up to ±.25°C during these experiments.

Dip times 5, 10, 15, 30, 40 and 50 sec plus combinations of some of these.

Since Davies, 1980, the widely used guide for handling salmon on freezer vessels, recommends dip times of "10 to 15 seconds for a minimum of two dips", a 15 sec first dip followed by a 10 sec second dip was selected as the standard throughout these experiments. Other values were used to investigate the effect of this parameter over a range that could practicably be used on the vessels. An interval time between dips of 30 sec was used to allow time for draining and weighing the fish but other values were also used to determine the influence of this factor.

Glaze thickness was measured by inserting pins through the glaze into the fish and then, by using a vernier caliper depth gauge reading to 0.001 in. (0.0254 mm), determining the distance from the head of the pin to the surface of the glaze. A small amount of the glaze was then carefully chipped off and the distance to the skin surface of the fish measured. The difference in the two readings was the glaze thickness. Two or three readings were made at different locations on each fish to obtain an average thickness.

For the storage tests two groups of 6 or 7 fish each in the size range from 3 to 4 kg were stored piled 2 high on a shelf in a coldroom at -28°C. Two fish from each group were in contact with the insulated outside wall. The airspeed over the fish was about 1.0 m/sec. One group of fish was left uncovered while the other was covered loosely with a plastic sheet. The fish were held for approximately 6 weeks and weighed periodically to determine the glaze loss. At the end of that time the fish were reglazed and the test was repeated with the two groups of fish being reversed in their treatment. The results were averaged to eliminate the effect of the size differences in the two lots of fish. For comparison with the above a similar test was done with a group of 6 fish held uncovered at the same temperature in a freezer in which there was no air motion.

To determine the rate of thawing on removal from a freezer two fish, previously fitted with thermocouples in the centre and under the skin, were taken from a cold room at a temperature of -28°C and left for 2 hr on a stainless steel table at an ambient temperature of 19°C. This would simulate the conditions that could be experienced when a fish is unloaded from a freezer vessel and left on a grading table or in a fish tote on the dock.

RESULTS AND DISCUSSION

1. General

Because they are required in the theoretical determination of glaze thickness as well as in the design of glazing, freezing and fish handling equipment, some basic measurements were made during this series of experiments to determine the physical dimensions, proportions and yield of Pacific salmon. These data are shown in Figure 1, which gives the relationship of length (fork length), width (maximum), thickness (maximum) and the round weight of salmon; Figure 2, which gives similar information for small farm salmon but based on a gutted, head-on weight; and Table 1, the yield of samples of each of the 5 species after gutting and heading. All of

these fish with the possible exception of 2 or 3 of the chum salmon were in prime condition, showing no signs of spawning changes (there were no hooked snouts or humped backs and gonads were still only partly developed).

2. Glaze water composition

Of the glaze solutions used, the half strength sea water (1.5% salt) gave the best looking glaze. It was clear, uniform and was quite resistant to breakage from minor bumps that might be experienced during normal handling under recommended conditions. Fresh water glaze was clear but cracks appeared as the glaze hardened and it was more brittle and tended to shatter more easily. Sea water glaze was slightly cloudy and at times it contained small patches of crystalline ice that flaked off very easily and resulted in dried spots on the skin. Sea water with the sugar additive gave a glaze with a slightly better appearance than just sea water but no noticeable improvement in the crushing or abrasion resistance could be detected. When the fish with the glaze with additive were thawed, however, the sugar left a slightly sticky or slimy film on the fish that could cause an adverse consumer reaction.

From these results it is recommended that wherever possible a mixture of approximately equal parts of sea water and fresh water be used for glazing on freezer vessels. Where sufficient fresh water (or fresh water ice) is not available the temperature of the fish during glazing and storage should be kept as far below -21.1°C (the eutectic temperature of a salt-water solution) as possible. Sugar based additives may provide some improvement if problems are experienced with sea water glazes but these problems may be an indication that the hold temperature is too high or fluctuating excessively and improvements to the refrigeration system may be required.

Statistically it was found that there was no significant difference in the amount of glaze picked up by the fish using any of these glaze solutions, all other factors being constant.

3. Glazing variables

A. General

A summary of all the data obtained is given in Tables 2 and 3. In each case these data were plotted with the fish weight (gutted, head-off or head-on) on the horizontal axis and the percent glaze on the vertical axis (Fig. 3 to 13). Regression analysis was used to obtain the "best-fit" curve for each set of data and in every case exponential regression, producing curves of the formula $G=Ae^{BW}$ where G is the glaze percentage, W the fish weight, A and B the coefficients, gave the highest correlation coefficient, r. An r value of 1.0 indicates perfect correlation of data and a value of 0, no correlation. The minus sign indicates an inverse correlation; that is as the fish weight increases the percent glaze decreases. Also shown in the table is S_G, the standard error of the estimate of the glaze, G. Ninety-five percent of the points will fall within 2 standard errors of the values given by the regression line. The statistical significance of the results were determined using the Student's "t"-test and these values are also shown in the table. For clarity the points will not be shown in all of the graphs to be presented but example distribution of points and the curves calculated for them are shown in Figures 3, 9 to 13, 26 and 27.

The scatter of the points in the graphs to be presented was due to normal experimental variations, difficulty in holding parameters perfectly constant, variations with time and season and, in particular, problems with glazing inside the belly cavity of the fish. Ideally, when frozen, the belly flaps of a salmon should gape open slightly (5-10 mm) to allow for inspection of the cavity and this also presents the maximum surface for glaze adherence. However, this opening was often frozen closed and on occasion the flaps were collapsed and touching over some area inside the cavity as can happen when the fish are frozen post rigor. This then resulted in less surface area being covered by glaze and hence a lower glaze percentage for a given weight of fish. In addition, with a closed belly flap, if the fish was lowered head-end first into the glaze tank, as is the usual practice, an air pocket was trapped inside the fish preventing full contact of the water to all the

cavity surfaces and reducing the glaze picked up. This is a potential problem that should be watched for when glazing on the vessels. If it is occurring corrective measures such as reversing the fish should be made to ensure that sufficient glaze coverage is given to the inside of the belly flaps to protect this high fat content area of the fish from dehydration and oxidation.

B. Fish size

The data summarized in Tables 2 and 3 are shown in detail in Figures 3 and 4 for head-off fish, temperature -28°C, glaze water temperature -1°C, and in Figure 5 for glaze water temperature 2.5°C. Similarly Figures 6 and 7 give results for a fish temperature of -25°C at glaze water temperatures of -1°C and 1.8°C respectively, and Figure 8, for -20.5°C fish at -1°C water temperature. Results for head-on fish are shown in Figure 9 for fish temperature of -28°C and water temperature of -1°C, and Figure 10 for fish temperature of -25°C, -1°C water. Farm fish, head-on are shown separately with an expanded weight scale in Figure 11 for -28°C fish temperature, -1°C water temperature, and Figure 12 for 2.5°C water temperature. Figure 13 gives results for these fish at -20.5°C and water temperature -1°C.

As previously mentioned these results all show that over the size range investigated, up to 10 kg, for any particular condition the percentage glaze decreased as the fish size increased. However this percentage glaze figure can be misleading and what is really needed is to know the thickness of glaze that corresponds to a given glaze percentage for a fish of any size. Although difficult and impractical to do under commercial conditions, glaze thickness was measured on 30 different fish during these experiments for a range of sizes and glaze amounts. From these measurements an empirical relationship was derived between the glaze percentage, thickness and the fish weight for head-off fish. In addition using the data of Table 1, an independent mathematical estimate of the relationship was made to confirm the "best fit" line through the experimental points. This computation involved determining the surface area of the fish assuming an elliptical cross section and included a calculation of the area inside the belly cavity and on the cut

surface at the head, and then using the relationship that (since the glaze thickness is small compared to the radius of curvature) the weight of glaze on a fish is equal to the total surface area x the average glaze thickness x the density of the ice. Very high correlation was obtained between the two methods of determination.

The relationship derived was that:

$$G = \frac{8.15t}{W^{.316}}$$

where G = glaze percentage
t = glaze thickness - mm
W = fish weight (gutted, head-off) - kg

For convenience this expression was plotted in 2 different ways in Figure 14 for some typical values. This graph can be used directly to give an estimate of the glaze thickness on any fish simply by weighing it and determining the glaze percentage. Ideally it would be very useful to have an instrument that could quickly and conveniently measure the thickness of the glaze on a fish and then these graphs could be used to give the percentage glaze without having to remove it from the fish by partial thawing. An ultrasonic thickness gauge was tried briefly in this application but was found to be unsuitable because it was expensive, awkward to use, difficult to get a reading, and would not operate at freezer temperatures.

It has been the industry practice to specify a 5 percent glaze as the requirement for effective glazing of salmon. However, as can be seen in Figure 14, with a 5 percent glaze all fish under 5 kg (a majority of all salmon landed) will have less than 1 mm of glaze on them and will not be adequately protected for any length of time under typical vessel and commercial cold storage conditions. A practical minimum of 1 or even 1.5 mm is recommended to preserve the quality of the fish under these conditions but this would require up to 12 percent glaze on the smaller fish. Obviously then, from the point of view of quality, glaze thickness not percentage is

the most important factor. Rather than specifying a 4 or 5 percent glaze requirement the industry would be better advised to have the freezer vessel operators adopt consistent glazing procedures that would ensure that a minimum thickness of at least 1 mm of ice is applied to every fish. This would cause some difficulty with determining the glaze allowance to be applied when the fish are weighed on landing because the glaze percentage could vary widely on fish of different sizes, however this is often the case now because of the difficulty in controlling the many glazing variables on the vessels. To determine the glaze allowance, a representative sampling of large and small fish should be selected from each lot of fish and the average amount of glaze determined by partially thawing the fish in cold water and weighing before and after removal of the glaze. This factor can then be applied to the whole load when calculating the fish weights to be used for final payments.

To make it possible to set up glazing procedures based on ensuring a specific glaze thickness, the empirical relationship of Figure 14 was used to convert the data from Figures 3 to 8 to show the glaze thickness deposited on fish of different sizes for each of the conditions used. These are shown in Figures 15 to 17. Interestingly these show that, if the glazing conditions were kept constant, the glaze thickness varied only slightly over the range of sizes tested. For instance, while the percentage glaze changed from 14% to 4.5% for fish at -28°C, water -1°C, 15 plus 10 sec dips, over the range of sizes from 1 to 9 kg (as shown in Figure 4), the thickness varied only from 1.8 to 1.2 mm. These figures also show that for fish temperatures of -25°C or colder, the 2 dips of 10 or 15 sec recommended in Davies (1980), will produce a suitable glaze of 1 mm or more as long as the glaze water temperature is kept near -1°C, but at higher water or fish temperatures insufficient thickness will be picked up particularly on the larger fish.

C. Dip times

For clarity the data were replotted in Figure 18 to show the variation in the percentage of glaze picked up with dip times. For a 2 kg fish, at a temperature of -28°C and water temperature -1°C, there is a steady increase

in the amount of glaze with increasing dip times up to 50 sec. At higher fish temperature, -25°C, however, the percentage glaze is maximum at about 40 sec and decreases thereafter and at higher water temperatures the glaze percentage peaks at about 15 sec.

D. Fish temperature

The effect of varying the fish temperature on the amount of glaze picked up is shown in Figure 19 for a 2 kg fish. It can be seen that the colder the fish the more glaze it picked up. Approx. 60 percent more glaze was picked up on a 2 kg fish (head-off) at -28°C than at -20.5°C. Similar results were obtained for head-on fish for the conditions shown. This points out that for maximum glaze deposition, the fish should be equilibrated to the lowest temperature of the freezer hold before they are glazed.

E. Glaze water temperature

The percentage glaze picked up at -1°C water temperature was compared with that at 2.5°C in Figure 20 for -28°C fish temperature and dips of 15 and 15 plus 10 sec, and in Figure 21 for -25°C fish temperature and 1.8°C water temperature at the same dip times. In addition Figure 22 shows the variation in glaze percentage for 15 and 15 plus 10 sec dips at a fish temperature of -25°C over a range of water temperatures using mean values from the -1°C and 2.5°C data plus additional points obtained at higher water temperatures for a 2 kg average fish size.

The water temperature is one of the most important factors in glazing and one of the most difficult to control. These figures show that the amount of glaze picked up decreased very rapidly as the water temperature was raised. At 2.5°C the amount picked up was only about 60 percent of that at -1°C for -28°C fish and at 1.8°C only about 55 percent of the amount at -1°C was picked up for -25°C fish. From Figure 22 it can be seen that above about 15°C no glaze at all was obtained under the conditions tested. On a fishboat, the glaze tank is filled with warm water and left in the freezer hold, or, if available, ice is used to prechill. Temperature control or

measurement is minimal and the water is quickly chilled to its freezing point when cold fish are being dipped into it. Periodic additions of warm water to counteract freeze-up could result in fluctuating glazing temperatures. Even under laboratory conditions it was difficult to control the glaze water at temperatures above the freezing point and this was reflected in the poor statistical correlation of the results obtained at the 1.8 to 2.5°C temperature. In order to adequately control this factor the glaze tank would have to be equipped with a stirrer and a thermostatically controlled electric heater.

F. Other factors

i. Head-on, head-off

A comparison of the difference in the percentage glaze picked up on sockeye, dressed head-on or head-off, is shown in Figure 23 for -28°C, -1.0°C temperatures. The difference was significant and reflected a proportionately greater increase in the surface area inside and outside the head than in its weight.

ii. Double dipping

Double dipping was found to be more efficient than single dipping. (This is also reported by Gora et al., 1972.) In every case in Figures 4 to 7 the 15 plus 10 sec dips produced greater amounts of glaze than a single dip of about the same total immersion time, 30 sec, and in fact, except for fish under about 2 kg in Figures 4 and 6, it produced more than any single dip up to 50 sec. The effect was particularly pronounced at higher water temperatures (Figures 5 and 7) where the amount of glaze decreased when the single dip time was increased from 15 to 30 sec while the double dip, 15 plus 10 sec, resulted in an increase in the amount of glaze by about 50% over that obtained on a single 15 sec dip. Double dipping is also reported to give a more pliable, better adhering and less brittle glaze (Gora et al., 1972).

When double dipping it was found that there was no noticeable difference in the amount of glaze picked up on the second dip for time intervals between dips from 20 sec up to a few minutes. After a 30 minute interval there was a slight increase in the amount of glaze picked up on the second dip and after 5-1/2 hr there was an increase of about 10%. Under the conditions of these tests it took from 8 to 12 hours interval between glazes before the second glaze was as much an an original glaze at the same dip time. This was related to the temperature rise and cool down period during and after glazing which will be discussed later.

Figure 24 shows the amount of glaze picked up on an original glaze of a fish compared to that picked up on reglazing. The glaze percentage on the reglazed fish was based on the total weight of the fish plus the residual glaze on it at the time of reglazing. There is a slight difference in the 2 curves but statistically there was no significant difference. Thus the graphs presented in this report can be used for either original or any subsequent reglazing of the fish.

In double dipping a dipping sequence of 15 sec, 30 sec, 10 sec (first dip, interval time, second dip) was compared with the reverse order; 10 sec, 30 sec, 15 sec and is shown in Figure 25. The two curves are almost identical and statistically there was no difference in the two sequences.

iii. Species difference

For the condition of head-off fish at a temperature of -28°C, glaze water temperature -1°C there were a sufficient number of points of all species that a difference was seen between the amount of glaze picked up by sockeye compared to all other species combined; as can be seen in Figures 26 and 27. The sockeye data were separated and compared statistically with the other species and the difference was found to be very significant. The maximum difference was found with larger sockeye; a 4 kg fish picked up approx. 3 percent less glaze after a 15 plus 10 sec dipping sequence. No significant differences were found between any other species or combination of species or between sockeye and the other species at any other of the test

conditions. The difference was probably attributable to a different ratio of surface area to volume or weight (shape factor) for gutted sockeye than for the other species.

iv. Farm fish

For convenience, the results for the small fish farm chinooks are shown separately in Figures 11 to 14 and give some typical glazing parameters that can be used by the fish farm operator when processing his fish. Similar results and trends with changes in the various parameters were obtained as had been found with the vessel caught fish. No glaze thickness measurements were attempted with these fish but indications were that, because they are very small, even higher glaze percentages would be required to ensure a minimum 1 mm ice layer to adequately protect the fish. However because they would be stored, transported and marketed differently than the vessel processed fish no direct comparisons can be made in this area.

G. Temperature changes in fish

Figure 28 shows the typical temperature response at three locations in the fish during the glazing process. A total of 9 such runs were made with the instrumented fish which ranged in size from 2 to 4.5 kg. Because the fish size, glaze amount and glazing conditions varied considerably for these fish the results are not directly comparable but they did show that the temperature just under the skin rose a maximum of 11 to 17°C in 2 to 4 minutes after the first dipping while the centre of the fish rose 8 to 11°C after about 10 minutes. When the fish were allowed to equilibrate on a shelf in the cold room, after 5 or 6 hours they were within 2 to 4°C of the storage temperature and it took 10 to 12 hours to return to the original temperature. In general the greater the amount of glaze applied to a fish, the more heat will be added and the greater the temperature rise will be. This points out that care should be taken to avoid applying too much glaze in a single treatment as this can partially thaw the fish.

The important point to be made from these results is that a considerable amount of heat is picked up by fish when they are glazed and this must be subsequently removed from the fish by the vessel's refrigeration system. Ideally immediately after dipping the fish should be placed on the freezer shelves for about 1 hr to harden the glaze and recool the fish but more usually space is not available for this and the fish are left in the cold storage area for the equilibration period. In this case the fish should at least be spread out to allow this heat to dissipate before they are stacked away or covered over in the pens. The extra load that this can impose on the cold storage refrigeration system can be considerable and the result could be fluctuating fishhold temperatures and excessive drying of the fish. For example, if 1 tonne of fish is coated with an average of 5% glaze, 19,000 kjoules (18,000 BTU) of heat is added to the fishhold and if this fish is recooled to within 2-3°C of the hold temperature in 6 hr (as was found) the heat load for that time would be about 3200 kj/hr (3000 BTU/hr). This would equal the load on the cold stores from heat coming through the insulation and from all other sources on a typical freezer troller. Vessels with marginal systems should glaze at times when the refrigeration systems are not heavily loaded to minimize temperature fluctuations.

Figure 29 shows the thawing rate a 4.6 kg fish could typically undergo during the unloading process at the dock. The temperature under the skin rose about 0.5°C per minute for the first 30 minutes and reached the freezing point in just over 2 hours. Smaller fish would thaw even faster. Obviously fish should be unloaded, sorted, weighed and put into cold storage as quickly as possible. The thawing of the surface of the fish will not only weaken the bond of the glaze to the fish and make it necessary to reglaze but also the heat that will have to be removed from a boatload of fish could impose a significant load on the cold storage facilities. Ideally fish that have been thawed in this manner should be put through a freezer to quickly return them to the storage temperature otherwise the very slow cooling that would be experienced in covered totes in the cold stores could result in some damage to the fish through denaturation.

H. Cold storage

The results of the storage studies at various conditions are shown in Figure 30. The "covered" and "uncovered" points show losses for the entire group of fish including the 2 fish that were also in contact with the wall. While the storage conditions will vary greatly from vessel to vessel and in various parts of a fishhold, these results illustrate representative glaze losses that could be experienced on a typical freezer vessel. Unprotected and exposed fish can lose well over 1 percent glaze per week and smaller fish could lose at an even faster rate. There is an obvious advantage to covering or otherwise protecting the fish from direct contact with moving air. These glaze losses could be considerably higher if there are frequent or large temperature fluctuations in the fishhold resulting from inadequate refrigeration equipment or incorrect operating procedures. Ideally the fish storage area should be separated from the freezers and have no air motion or temperature fluctuation. Very little glaze loss was experienced on these tests under still air conditions even with uncovered fish. The importance of not stacking the fish in contact with the fishhold linings is also shown. An airspace should be provided between the linings and the fish so that the heat that comes through the floor and walls of the fishhold can be dissipated before it reaches the fish.

These results point out the extreme difficulty the freezer vessel operator would have in maintaining a constant and consistent glaze on all of his fish. Not only are there the many variables of applying the glaze but, in addition, the fish could be losing glaze at different rates, depending on their location in the fishhold, and for different times ranging from several weeks to a few days over the duration of the trip. Since the prime concern is the maintenance of fish quality and it is inconvenient to have to frequently reglaze the fish it is recommended that, first of all, the precautions of stacking and covering the fish discussed previously are taken and then, if the vessel is known to have a problem with dehydration, to apply sufficient extra (perhaps double) glaze at the first part of the trip and normal glazing at the end so that all fish will have sufficient glaze covering them when they are landed.

I. Weighing fish on landing

Each landing of freezer vessel salmon should be sampled and the average amount of glaze on the fish determined to establish the glaze allowance to be applied. Since glaze percentage varies with fish weight, a representative sample of both large and small fish should be chosen from the load or from each species or size group (eg. medium red chinook, etc.). The amount of glaze on each fish should then be determined by weighing the sample before and after removing the glaze by partial thawing in cold water.

If w_1 is the weight of the sample before deglazing (fish plus glaze), and w_2 is the weight of the sample after deglazing (fish only),

then the glaze allowance is: $\frac{w_1 - w_2}{w_1}$

The average glaze allowance from all the fish in the sample can then be determined and then this fraction subtracted from the total load to determine the actual weight of fish being landed. Note that the glaze allowance is not the same as the glaze percentage which is defined as:

$$\frac{w_1 - w_2}{w_2}$$

The glaze percentage is based on the weight of the fish while the glaze allowance is based on the weight of fish plus glaze.

4. Tuna

Because many salmon freezer vessels also participate in the tuna fishery, reference data similar to that previously given for salmon is included in the Appendix for a small sampling of albacore tuna. The glazing data are given for the fish round (ungutted, head-on) as they are normally landed in that condition but it is also shown that if the fish were headed and gutted, 21% of the freezing load could be saved and more fish could be

stored in the hold space available in these vessels. Although these fish have not normally been bled or gutted and only occasionally glazed after freezing on the vessels, indications are that significant quality improvement could be made if these procedures were adopted.

CONCLUSIONS AND RECOMMENDATIONS

Glazing of fish is important on freezer vessels to protect them from loss of quality and weight during the time they are held in cold storage. The amount of glaze a fish will pick up depends on a number of factors; fish weight and temperature, water temperature, dip time and number of dips, fish species and configuration. In addition the fish loses glaze during the time in the cold stores at a rate dependent on the storage conditions which can vary widely. Since many of these parameters are superimposed on each other and since control and even measurement of some of the factors is difficult if not impossible on a small vessel at sea, it is not reasonable to expect a freezer boat to land a load of fish in which there is a uniform or specific amount of glaze on every fish.

The important thing is to preserve the quality of the fish. To accomplish this it is necessary only to set up glazing procedures (using the data presented in this report) that will ensure that each fish has a minimum of approximately 1 mm of glaze. This will mean the glaze percentage could vary widely throughout the load and the difficulty is that payment must be made on the total weight of fish without having to remove all of the glaze to determine it. A representative sampling of the load should be taken and the average glaze allowance determined. The development of a simple instrumental means of measuring glaze thickness would greatly facilitate this sampling.

Because the glazing and storage conditions vary greatly from vessel to vessel, specific advice on glazing methods cannot be made. However the following general recommendations summarizing the findings of this report are made to help in setting up glazing procedures that can be used on any vessel to ensure that an appropriate amount of glaze is applied to every fish.

1. Every freezer vessel should be equipped with a good quality thermometer to periodically measure the temperature of the fish in the hold and of the glaze water.

2. For the glaze solution, wherever possible and unless otherwise specified by the buyers, a mixture of approximately 50% sea water and 50% fresh water should be used for best results. If no fresh water or ice is available, pure sea water can be used but frequent reglazing may be necessary unless the hold is maintained at a constant temperature of -26°C or lower.

3. All fish should be processed and frozen according to good handling practices and allowed to equilibrate to the lowest possible temperature of the fishhold (-26°C or lower by Inspection regulations) before glazing.

4. The glaze water should be cooled and kept at the lowest practical temperature during glazing. The freezing point of a 50:50 mixture of fresh and salt water is about -0.3 to -1.0°C and the solution will be at that temperature when ice starts to form around the edge of the container. Excessive freeze up can be overcome by periodically replacing a bucket full of the mixture with warm water and mixing thoroughly. The glaze water should be replaced regularly to prevent bacterial contamination.

5. Knowing the approximate fish and water temperature and using the graphs presented in this report the appropriate dip times can then be selected for any desired amount of glaze. The recommended two dips of 10 to 15 sec will produce an adequate glaze of 1 mm or more on most fish providing the fish temperature is below -26°C and the water temperature is near the freezing point. Larger fish will require repeated glazing to ensure the minimum glaze thickness. Depending on the characteristics of the fishhold it may be necessary to glaze more heavily at the beginning of the trip, to reglaze part way through the trip, or both, to ensure that

the fish do not lose so much glaze by sublimation that dehydration or freezer burn occurs and the fish are damaged before the trip ends.

6. Loss of glaze in the freezer storage can be minimized be maintaining the fishhold at a low (-26°C or below) and steady (±2°C or less) temperature, by protecting the fish from moving air by the use of ice blankets, plastic sheets or bags, and by preventing the fish from directly contacting the fishhold linings.

7. When unloading, the fish should be handled gently to prevent damaging the glaze and should not be left more than a few minutes on the dock before being transferred to the cold storage. Representative samples should be drawn from the load and the glaze allowance determined by the method outlined in this report. If properly done these fish can then be refrozen without significant damage.

8. Similar procedures can be followed for fish farm fish or for any other salmon frozen in shore plants. On shore there is much greater opportunity to measure and regulate the glazing conditions and to segregate the fish into similar sizes or species for each batch to be dipped so that much better control of the glaze amount should be possible.

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TABLE 1.

YIELD OF DRESSED SALMON.

Head-off

Sockeye	.80 (.02)	n=68
Chum	.77 (.03)	n=18
Coho	.74 (.03)	n=9
Pink	.78 (.025)	n=7
Chinook	.77 (.03)	n=3

Head-on

Sockeye	.89 (.02)	n=5

Values are average of n fish dressed weight compared to round weight (standard deviation in parentheses).

TABLE 2.

SUMMARY OF RESULTS FOR DRESSED HEAD-OFF FISH.

Fish temp.°C	Water temp.°C	Dip time(s) sec	Size range, kg	No. samples	Coeff. r	S_G	"t" test[1] level	Comments
-28	-1	15	0.8-8.9	39	-.74	.17	<0.1%	All species
		15 + 10	0.8-8.9	38	-.80	.14	<<0.1%	" "
		15	1.7-3.6	22	-.61	.13	<1%	Sockeye only
		15 + 10	1.7-3.6	22	-.79	.09	<0.1%	" "
		15	0.8-8.9	17	-.98	.06	<<0.1%	Other species
		15 + 10	0.8-8.9	16	-.98	.06	<<0.1%	" "
		10	0.9-4.9	16	-.84	.10	<<0.1%	All species
		10 + 15	0.9-4.9	9	-.86	.07	0.1-1%	" "
		10	1.1-5.0	24	-.89	.11	<<0.1%	Reglaze, all species
		5	1.1-6.0	7	-.95	.04	0.1%	Mixed species
		30	0.4-5.0	27	-.86	.10	<<0.1%	All species
		50	0.5-3.7	10	-.93	.08	<0.1%	Mixed species
-28	2.5	15	1.1-5.6	22	-.68	.14	<0.1%	All species
		15 + 10	1.1-5.6	22	-.66	.11	<0.1%	" "
		30	0.9-3.6	9	-.76	.12	0-5%	Mixed species
-25	1	15	0.7-9.2	22	-.75	.17	<0.1%	All species
		15 + 10	0.7-9.2	22	-.79	.15	<0.1%	" "
		40	1.0-3.6	9	-.80	.08	1-5%	Mixed species
		50	1.2-3.6	8	-.76	.10	1-5%	" "
-25	1.5	15	1.0-5.6	10	.63	.24	5%	Mixed species
		15 + 10	1.0-5.6	10	.60	.24	5%	" "
	2.0	30	0.9-3.3	6	.35	.11	>5%	" "
-20.5	-1	15	0.7-5.5	10	-.89	.21	<0.1%	Mixed species
		15 + 10	0.7-5.5	10	-.92	.16	<0.1%	" "

[1] "t" test definitions
0.1% level - highly significant result could occur by chance only once/1000 trials
1.0% level - significant result could occur by chance only once/100 trials
5% level - probably significant result could occur by chance only once/20 trials

TABLE 3.

SUMMARY OF RESULTS FOR DRESSED HEAD-ON FISH.

Fish temp. °C	Water temp. °C	Dip time(s) sec	Size range kg	No. samples	Coeff. r	S_G	"t"[1] test level	Comments
-28	-1	15	0.7-3.6	7	-.96	.04	<0.1%	Sockeye
		15 + 10	0.7-3.6	7	-.95	.05	<0.1%	"
-25	-1	15	0.7-3.3	7	-.85	.10	1-5%	"
		15 + 10	0.7-3.3	7	-.94	.07	0.1-1.0%	"
-28	-1	15	0.4-1.1	8	-.90	.06	0.1-1.0%	Farm fish
		15 + 10	0.4-1.1	8	-.91	.05	0.1-1.0%	" "
		5	0.4-1.0	5	-.84	.07	>5%	" "
		5 + 5	0.4-1.0	5	-.94	.05	1-5%	" "
-28	2.5	15	0.5-1.1	6	-.49	.95	>5%	" "
		15 + 10	0.5-1.1	6	-.41	.80	>5%	" "
-20.5	-1	15	0.4-1.0	6	-.85	.04	1-5%	" "
		15 + 10	0.4-1.0	6	-.86	.04	1-5%	" "

1 "t" test definitions
- 0.1% level - highly significant result could occur by chance only once/1000 trials
- 1.0% level - significant result could occur by chance only once/100 trials
- 5% level - probably significant result could occur by chance only once/20 trials

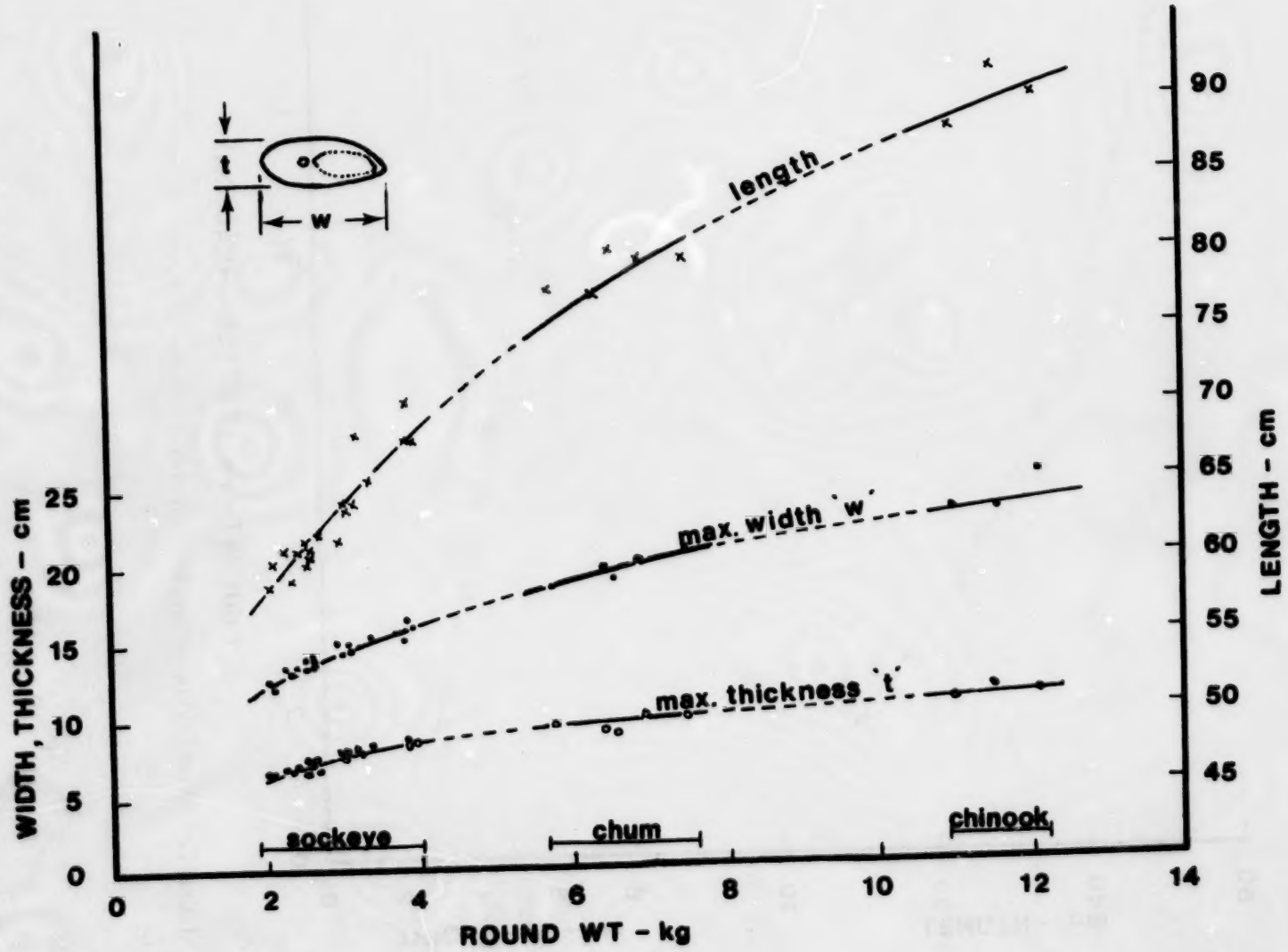


Figure 1. Weight/size relationships for salmon.

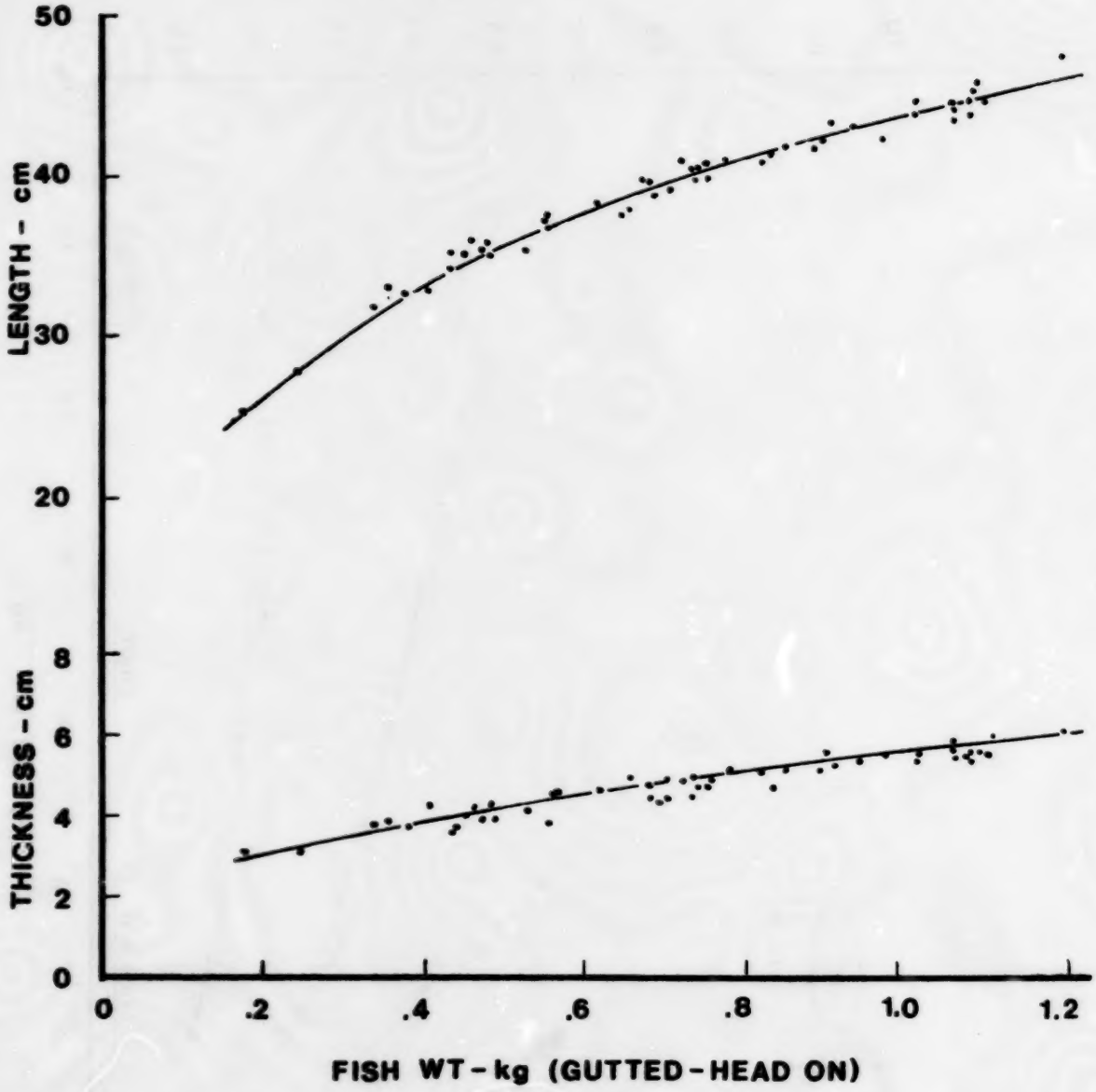


Figure 2. Weight/size relationships for fish farm chinook salmon.

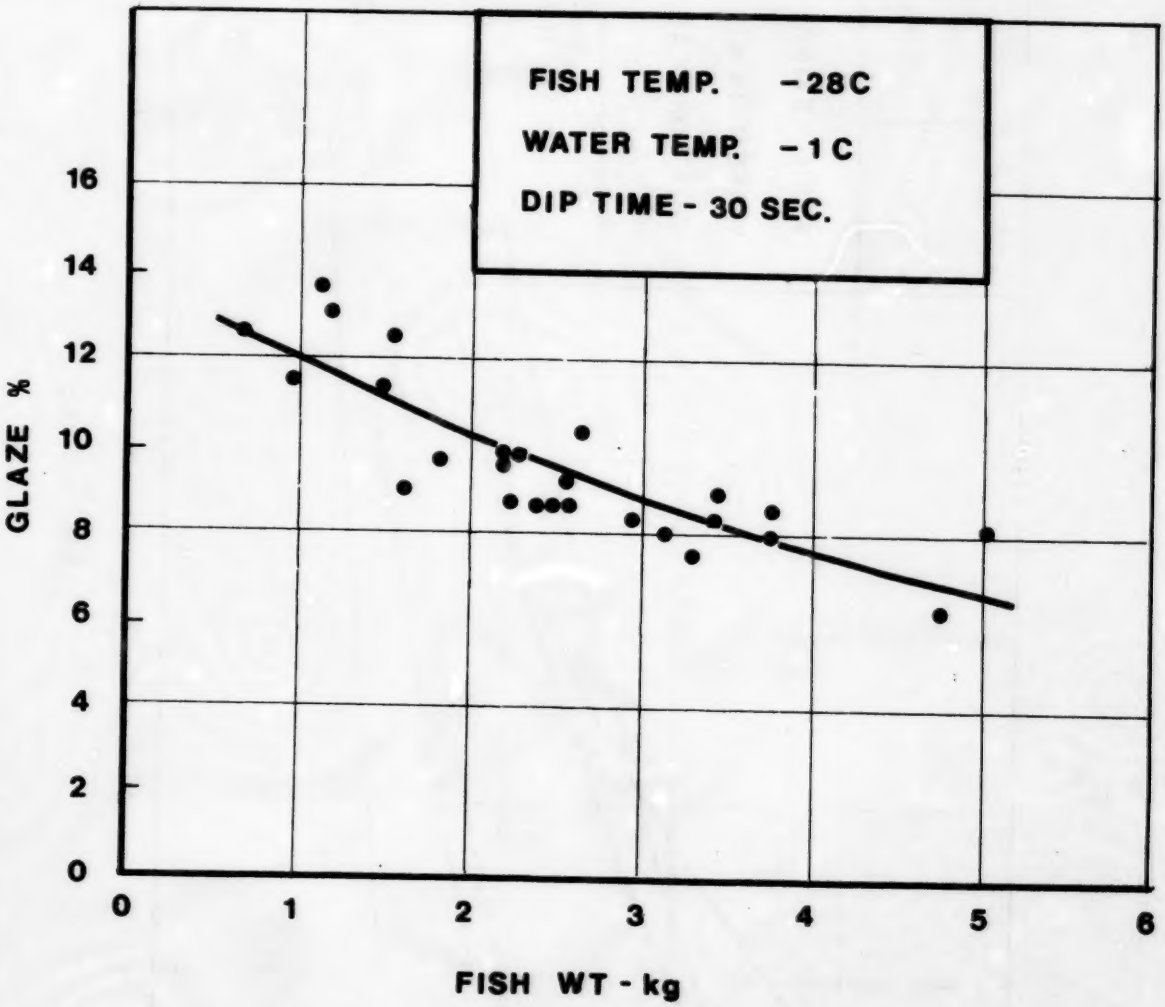


Figure 3. Example point distribution - glaze %/fish wt.

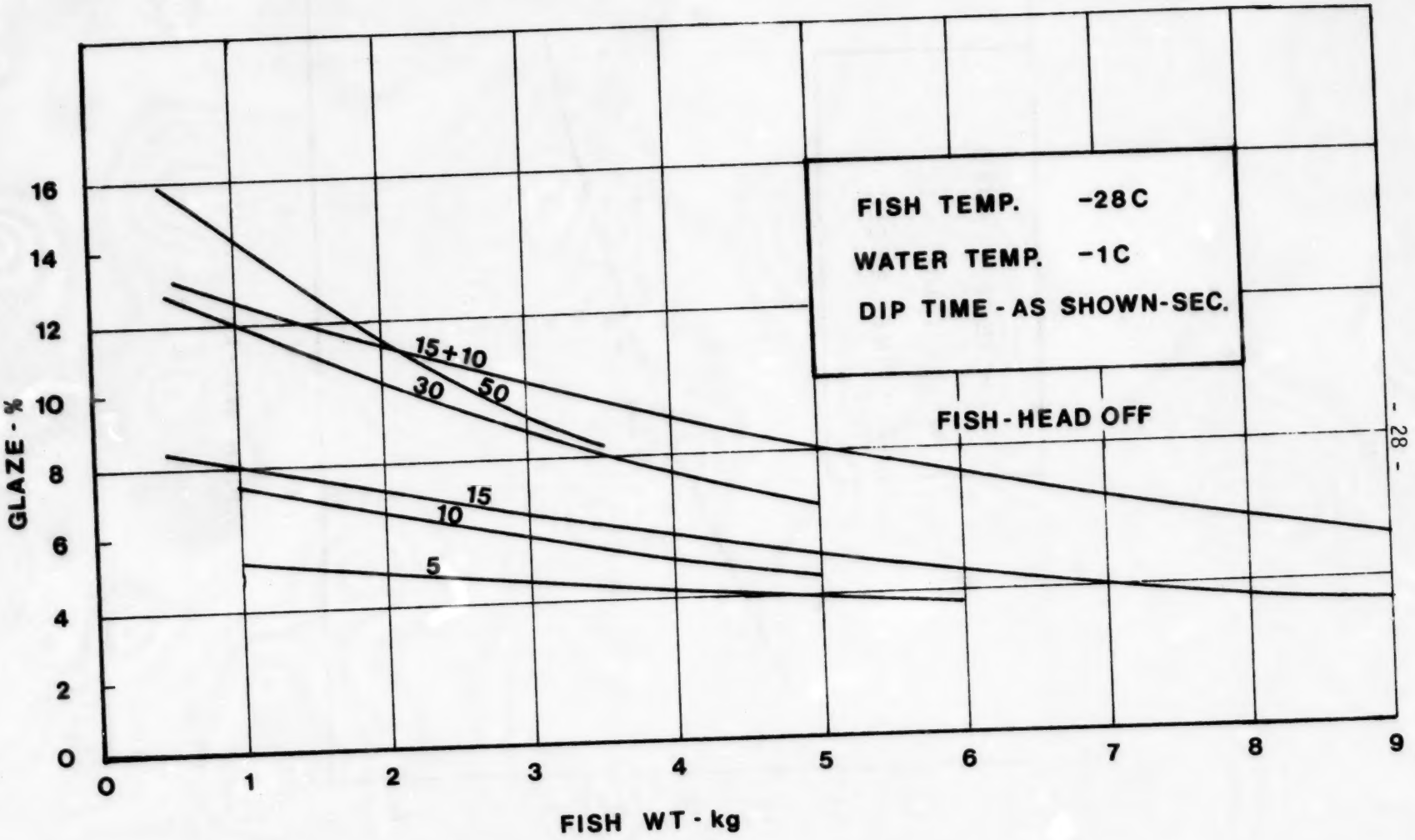


Figure 4. Glaze %/fish wt for fish temp. -28°C, water temp. -1°C.

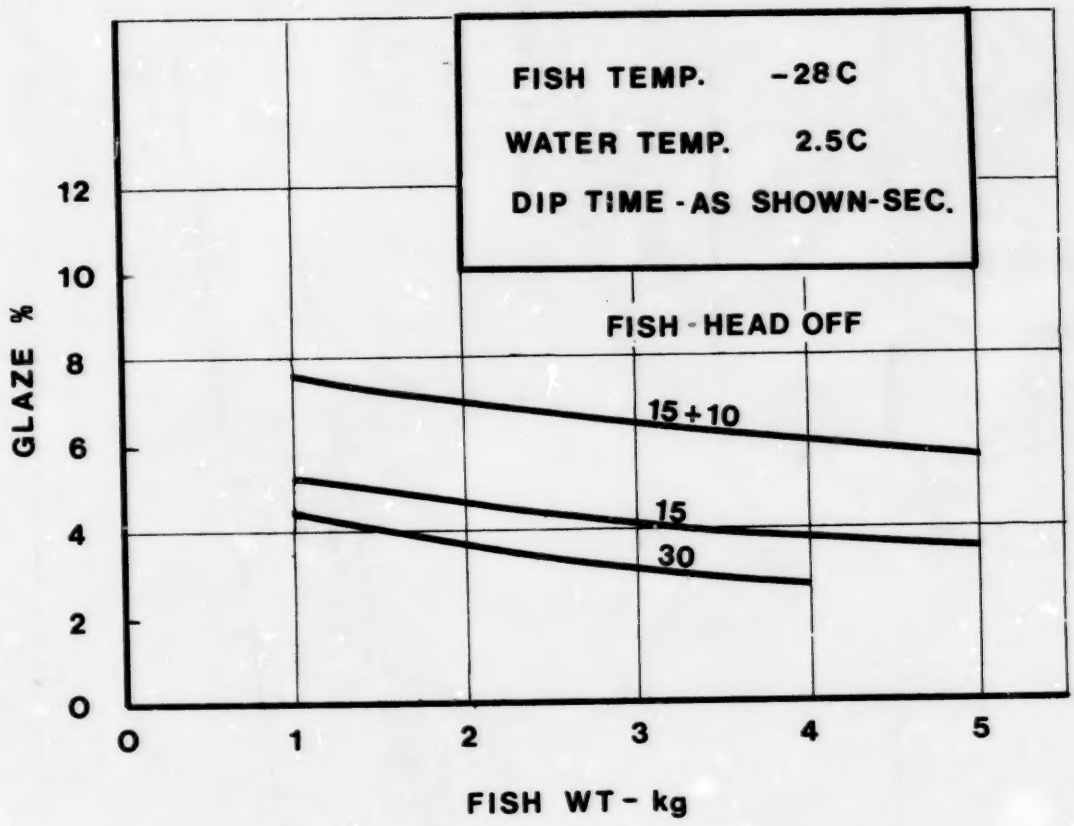


Figure 5. Glaze %/fish wt for fish temp. -28°C, water temp. 2.5°C.

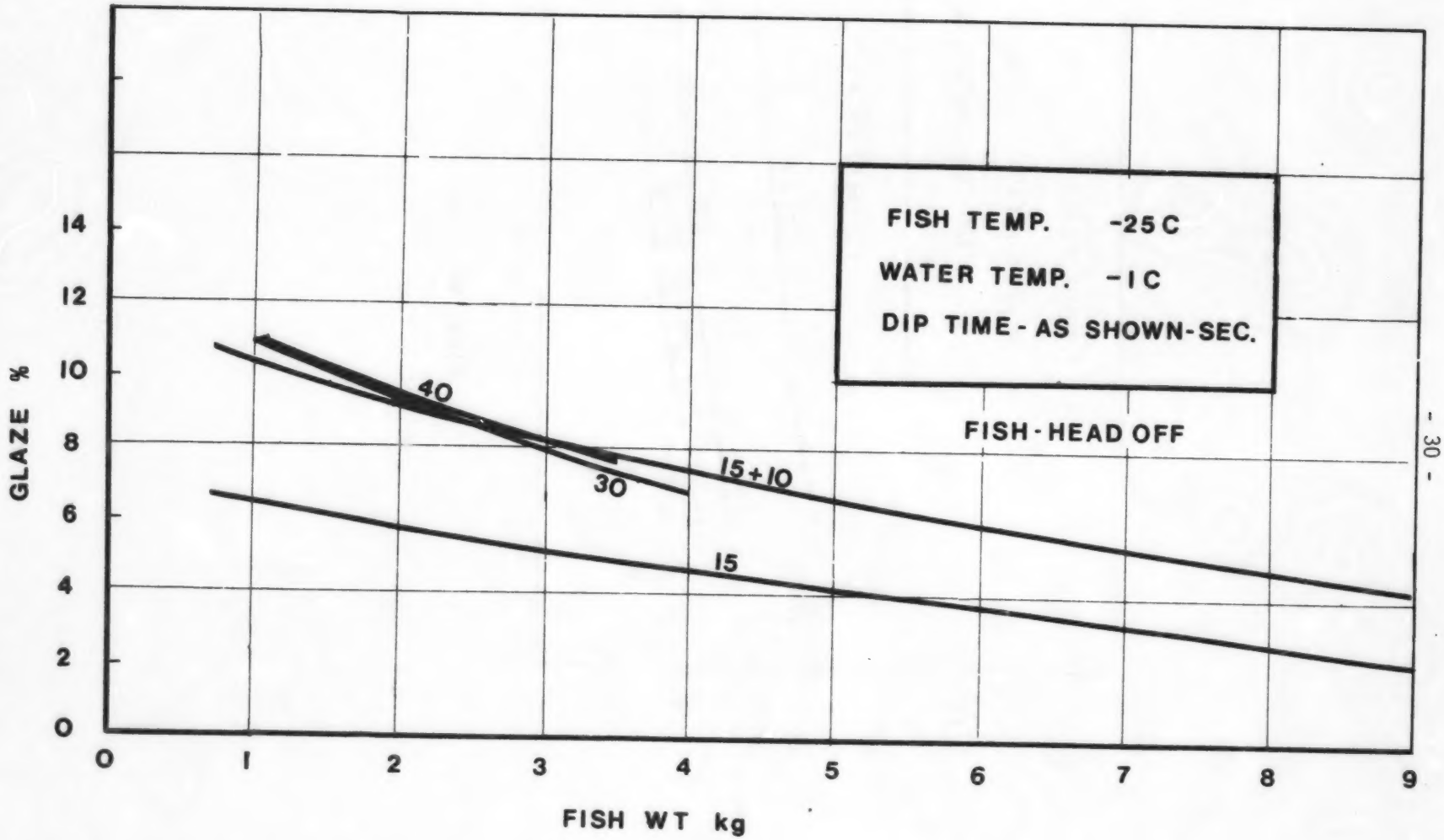


Figure 6. Glaze %/fish wt for fish temp. -25°C, water temp. -1°C.

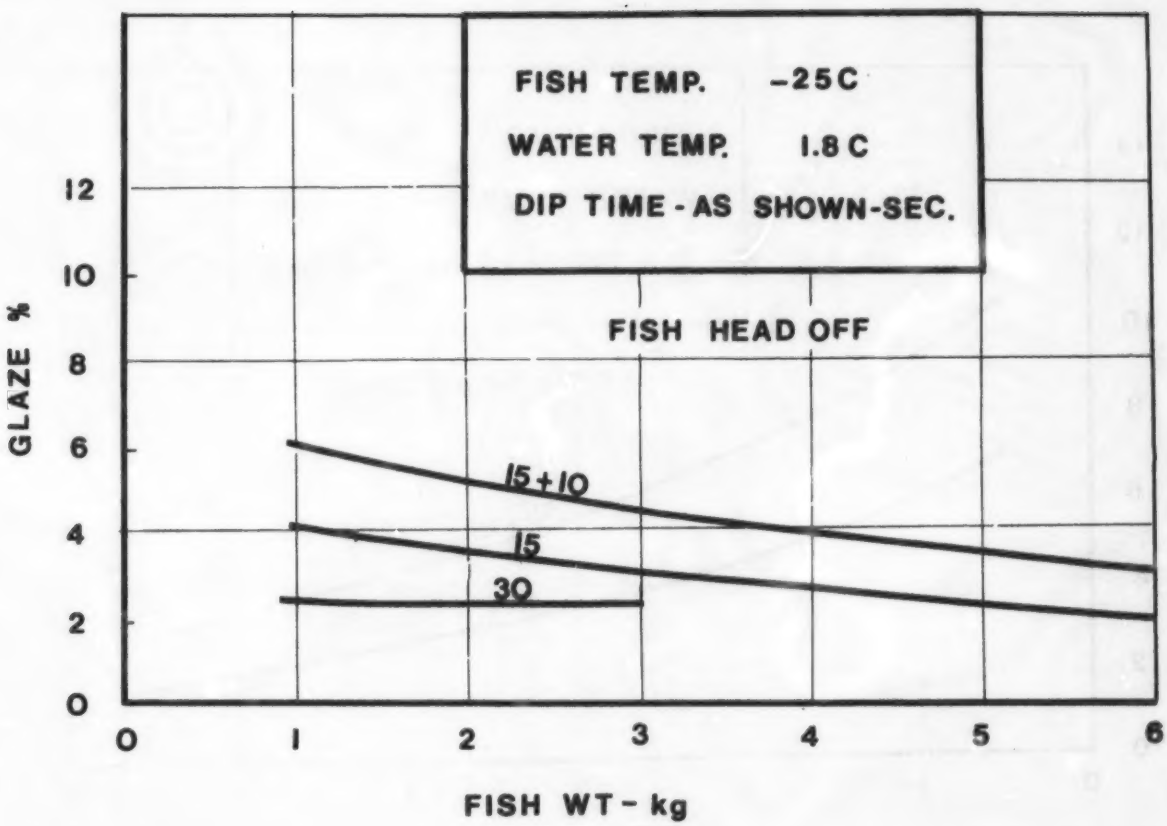


Figure 7. Glaze %/fish wt for fish temp. -25°C, water temp. 1.8°C.

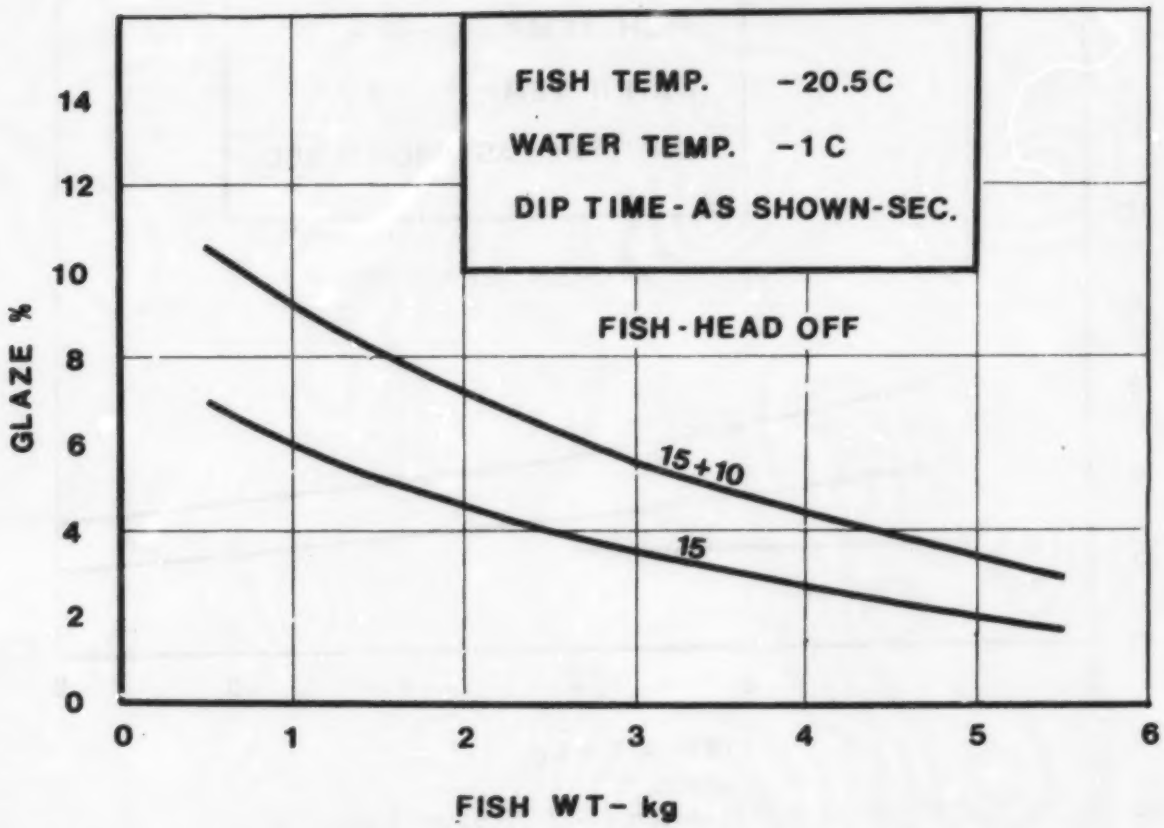


Figure 8. Glaze %/fish wt for fish temp. -20.5 °C, water temp. -1°C.

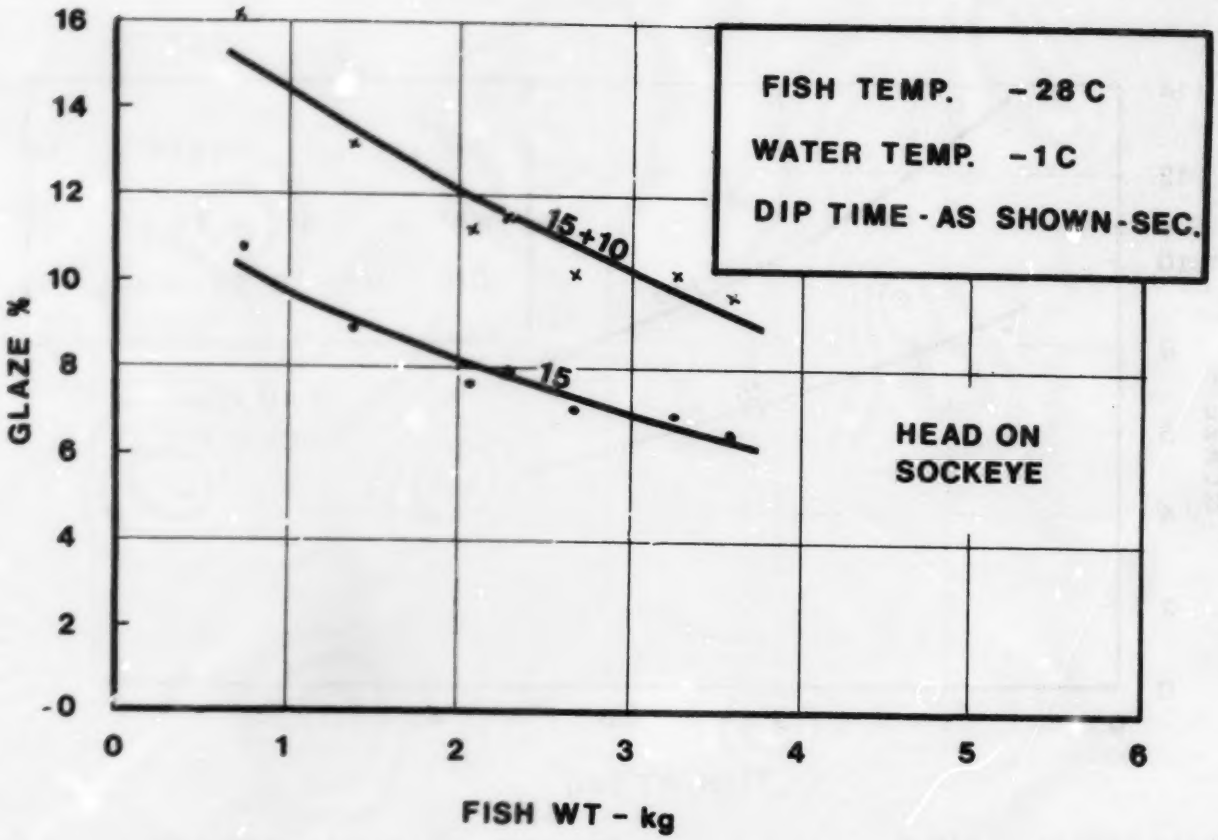


Figure 9. Glaze %/fish wt for head-on sockeye temp. -28°C, water temp. -1°C.

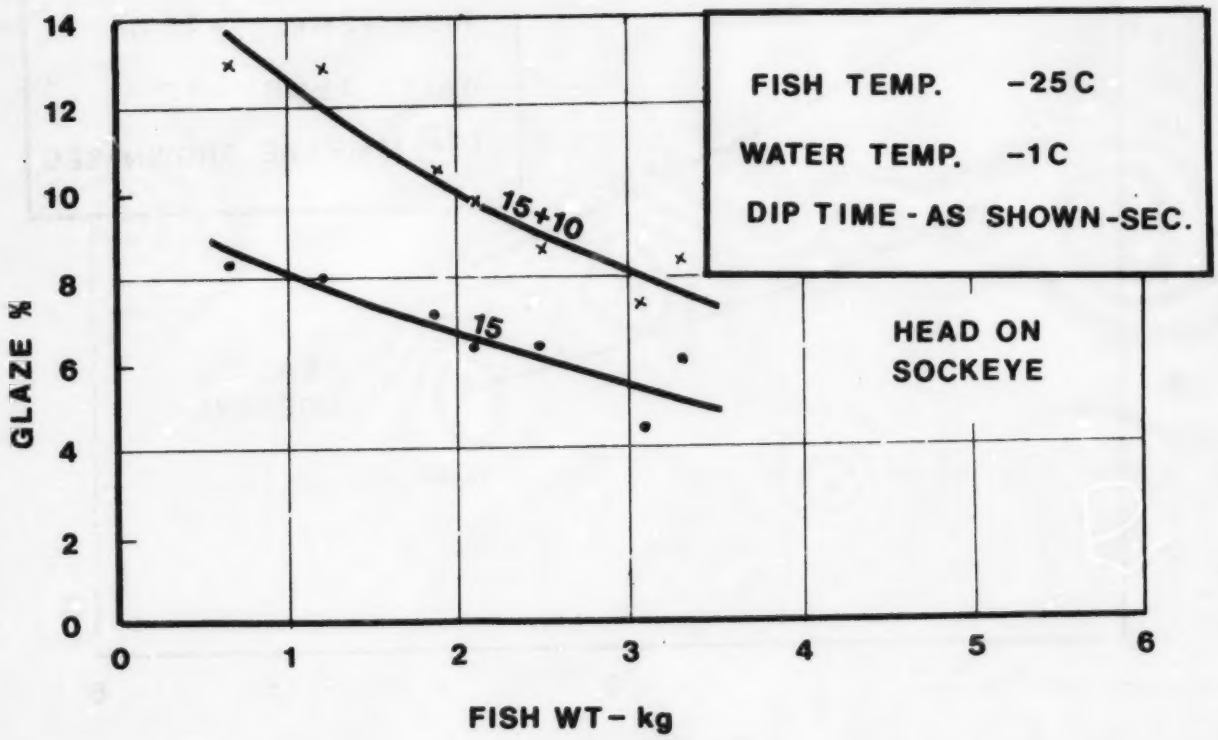


Figure 10. Glaze %/fish wt for head-on sockeye temp. -25°C, water temp. -1°C

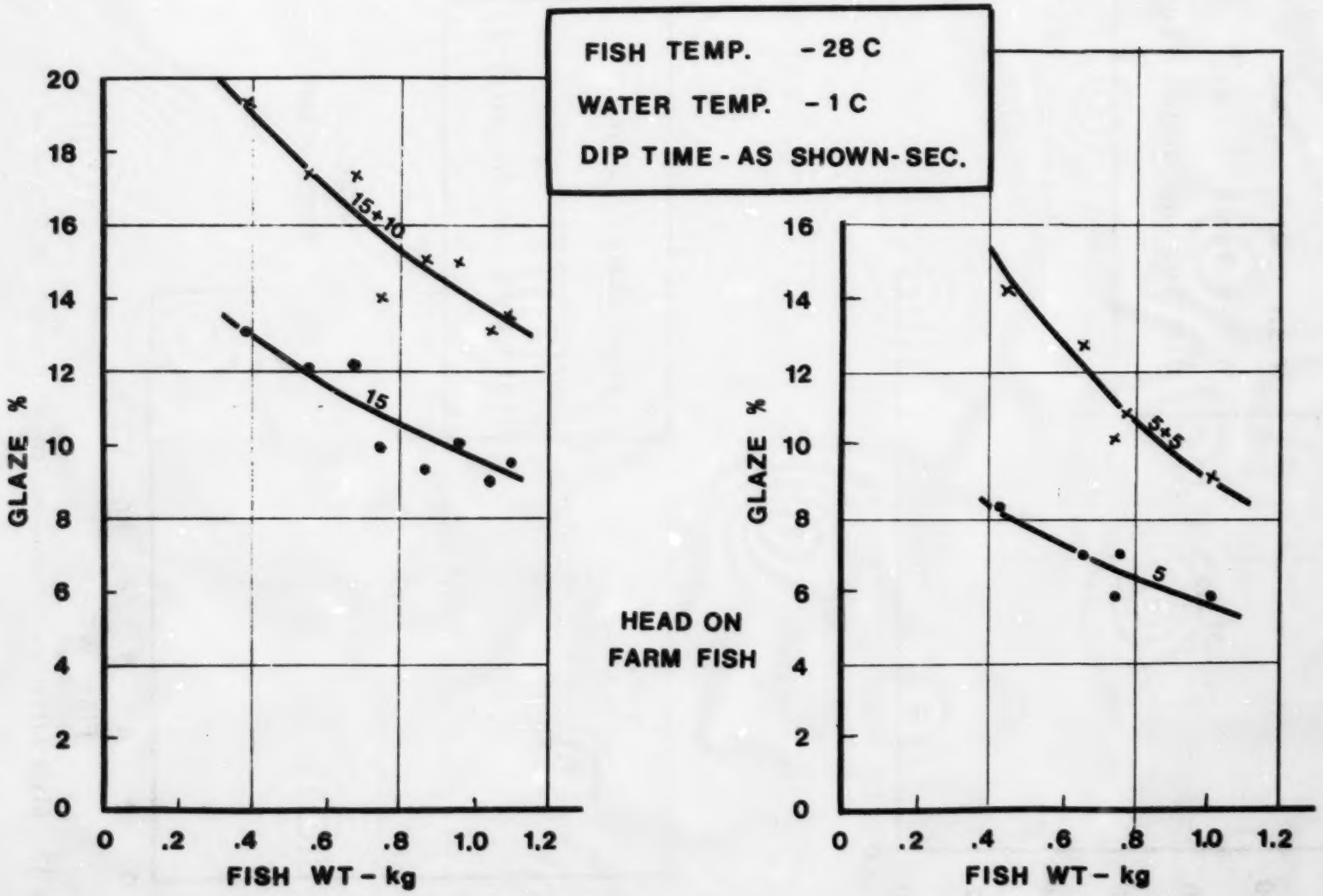


Figure 11. Glaze %/fish wt for head-on farm fish temp. -28°C, water temp. -1°C

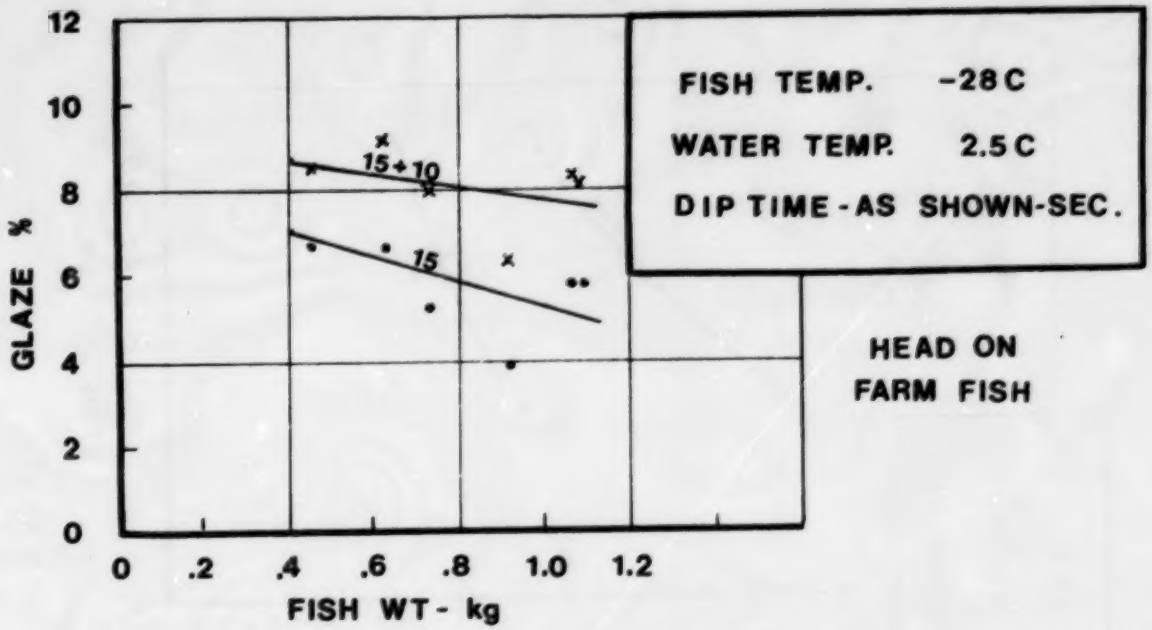


Figure 12. Glaze %/fish wt for head-on farm fish temp. -28°C, water temp. 2.5°C.

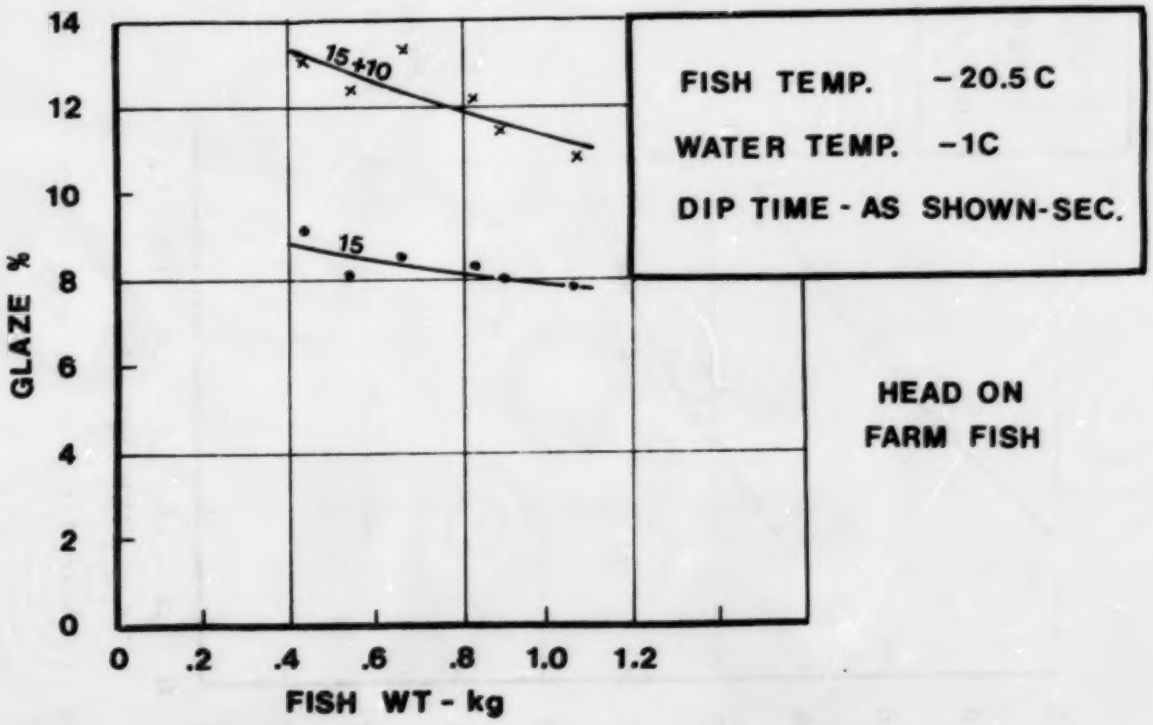
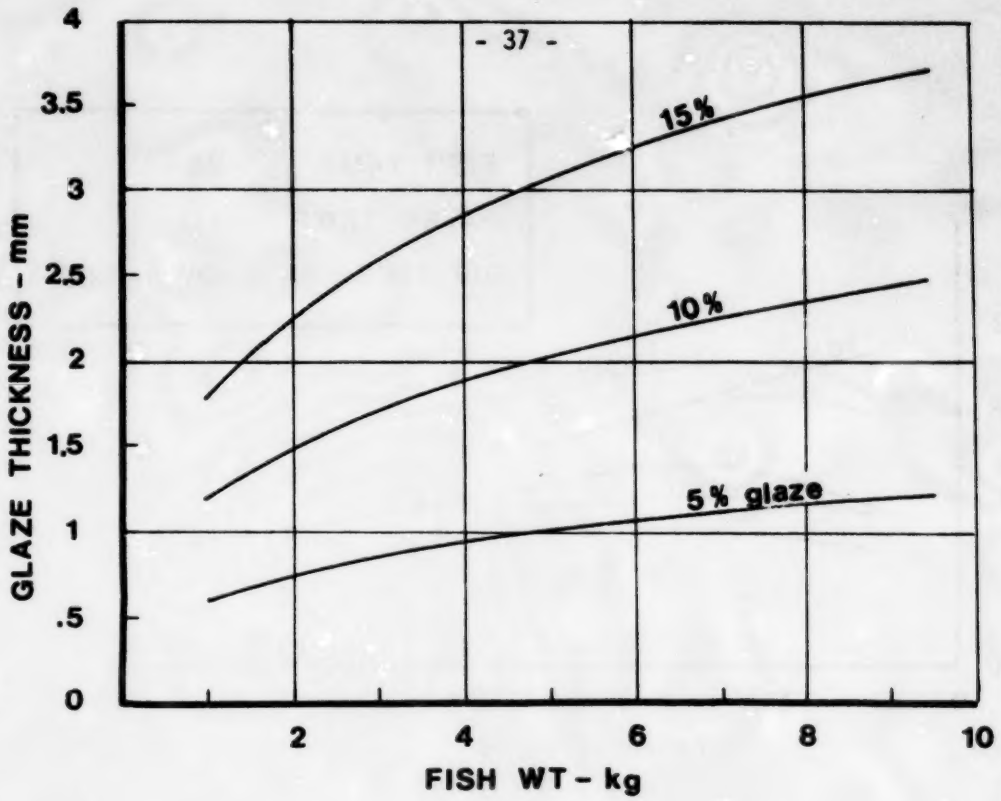


Figure 13. Glaze %/fish wt for head-on farm fish temp. -20.5°C, water temp. -1°C.



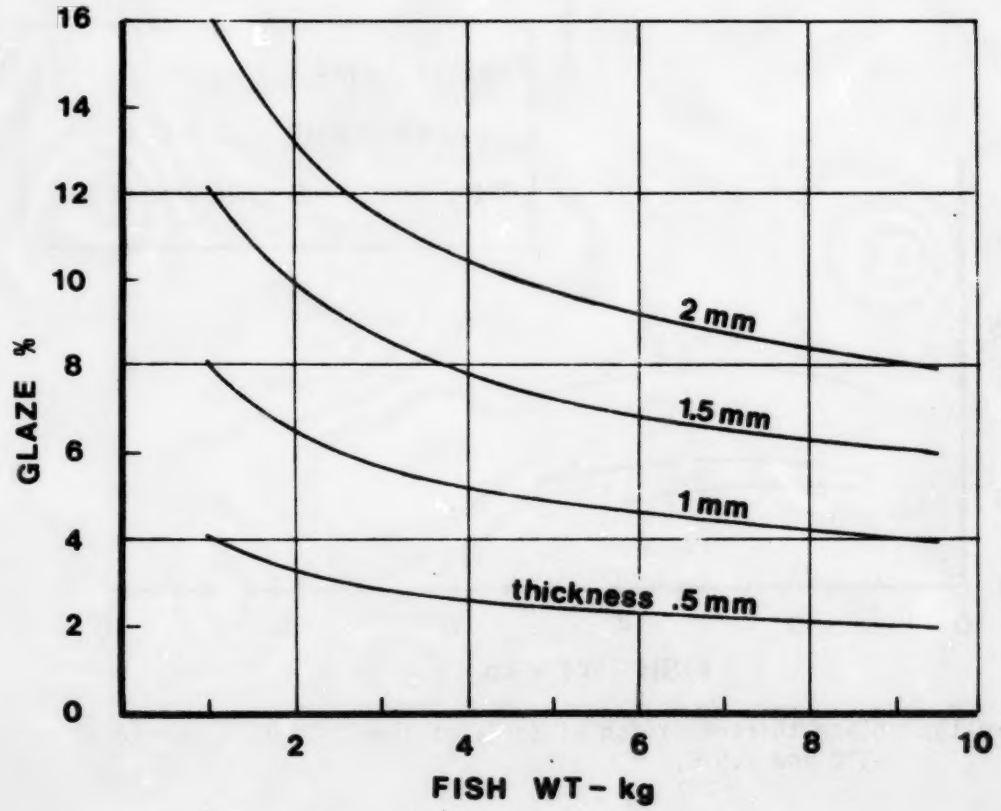


Figure 14. Empirical glaze %/thickness relationship.

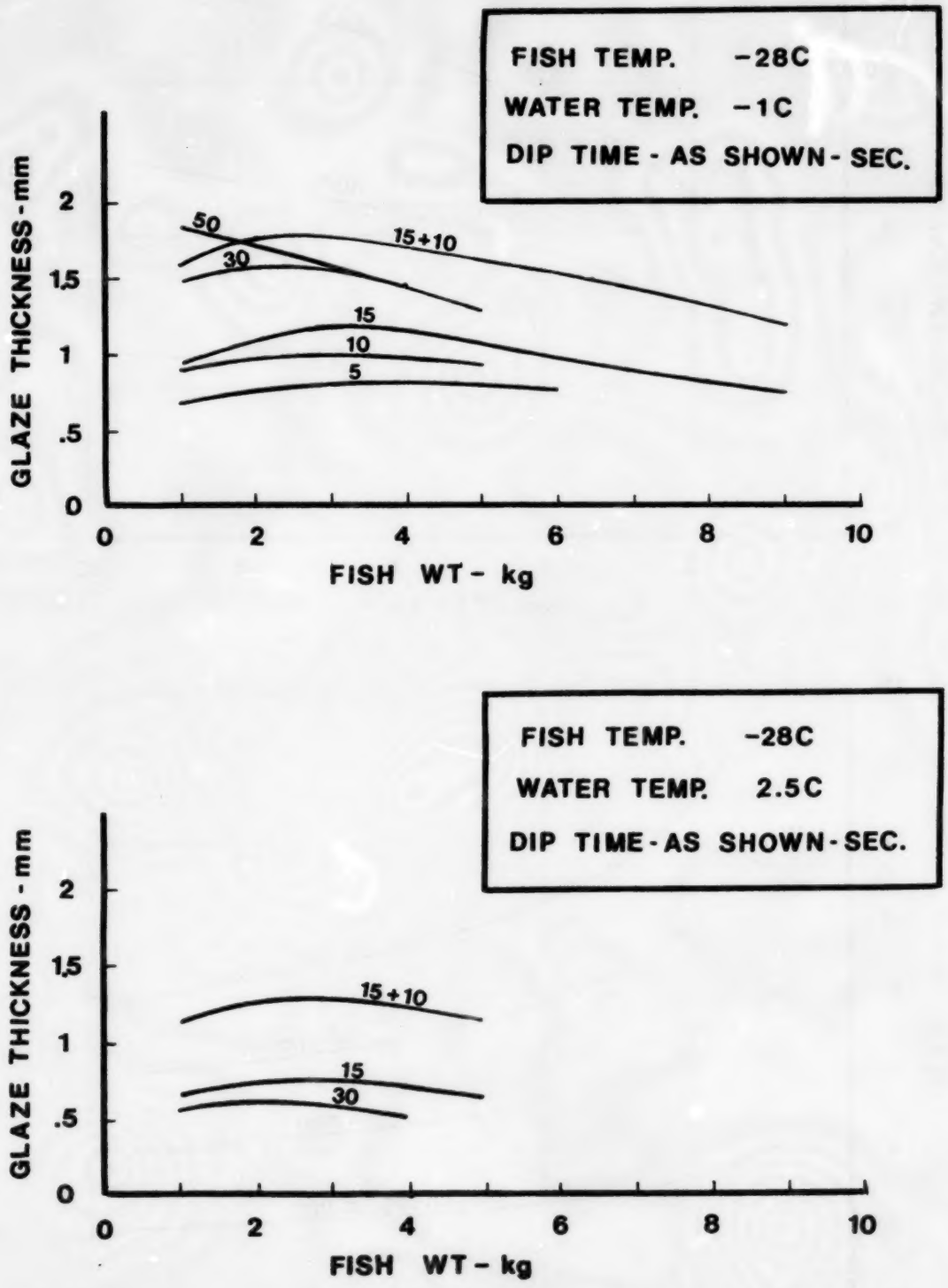


Figure 15. Glaze thickness/fish wt for fish temp. -28°C, water temp. -1°C and 2.5°C.

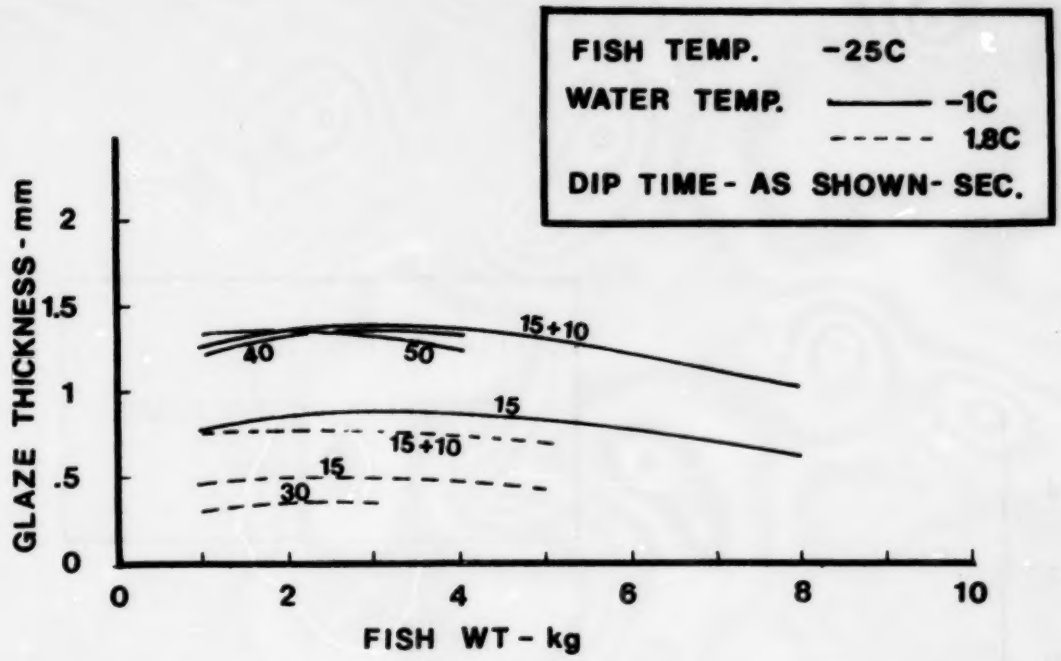


Figure 16. Glaze thickness/fish wt for fish temp. -25°C, water temp. -1°C and 1.8°C.

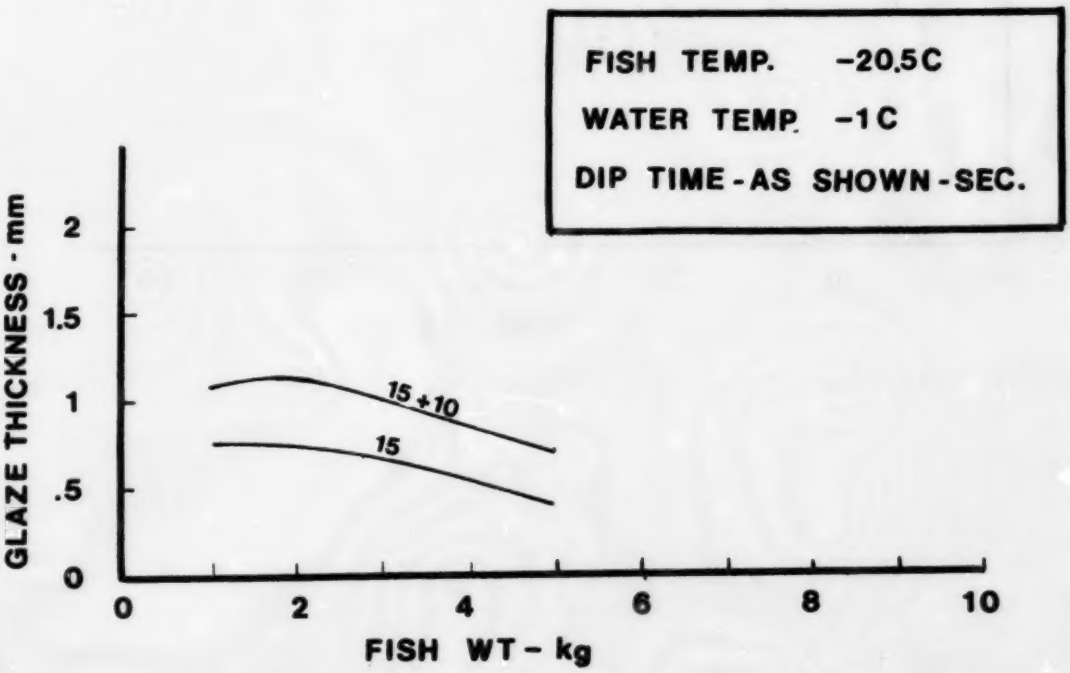


Figure 17. Glaze thickness/fish wt for fish temp. -20.5°C, water temp. -1°C.

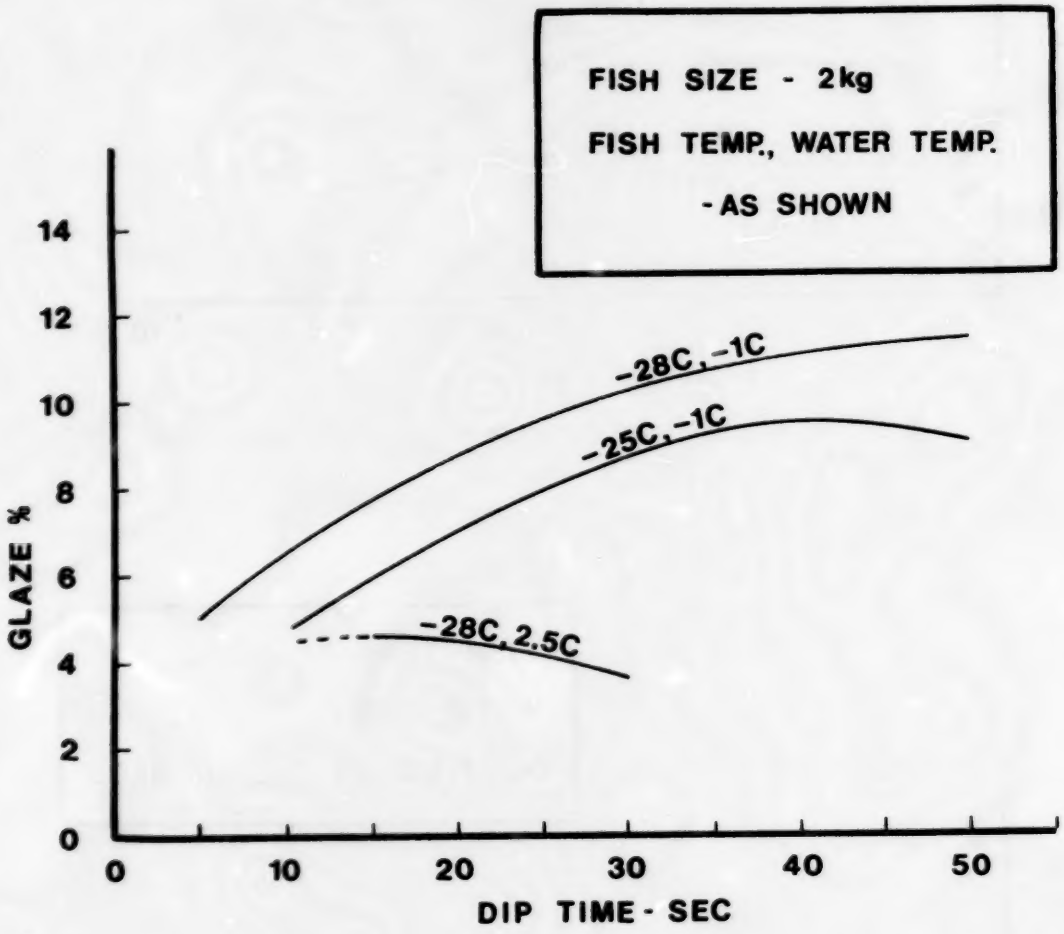


Figure 18. Variation of glaze % with dip time.

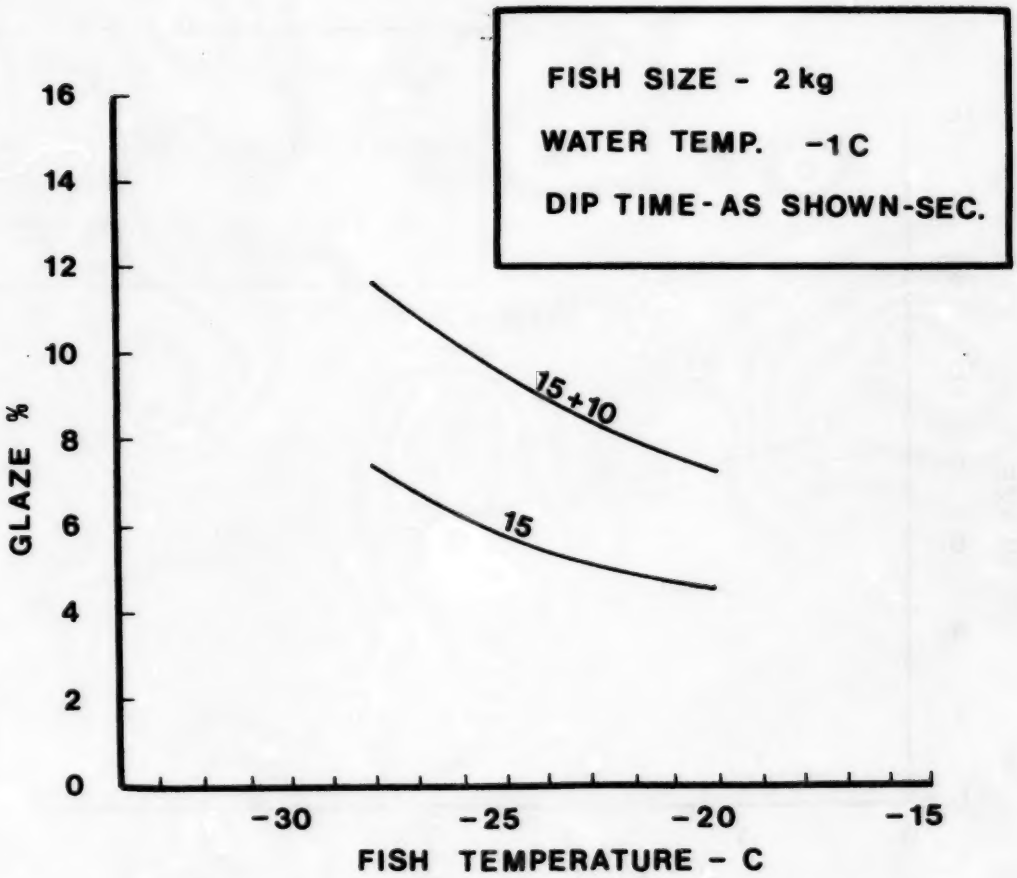


Figure 19. Variation of glaze % with fish temperature.

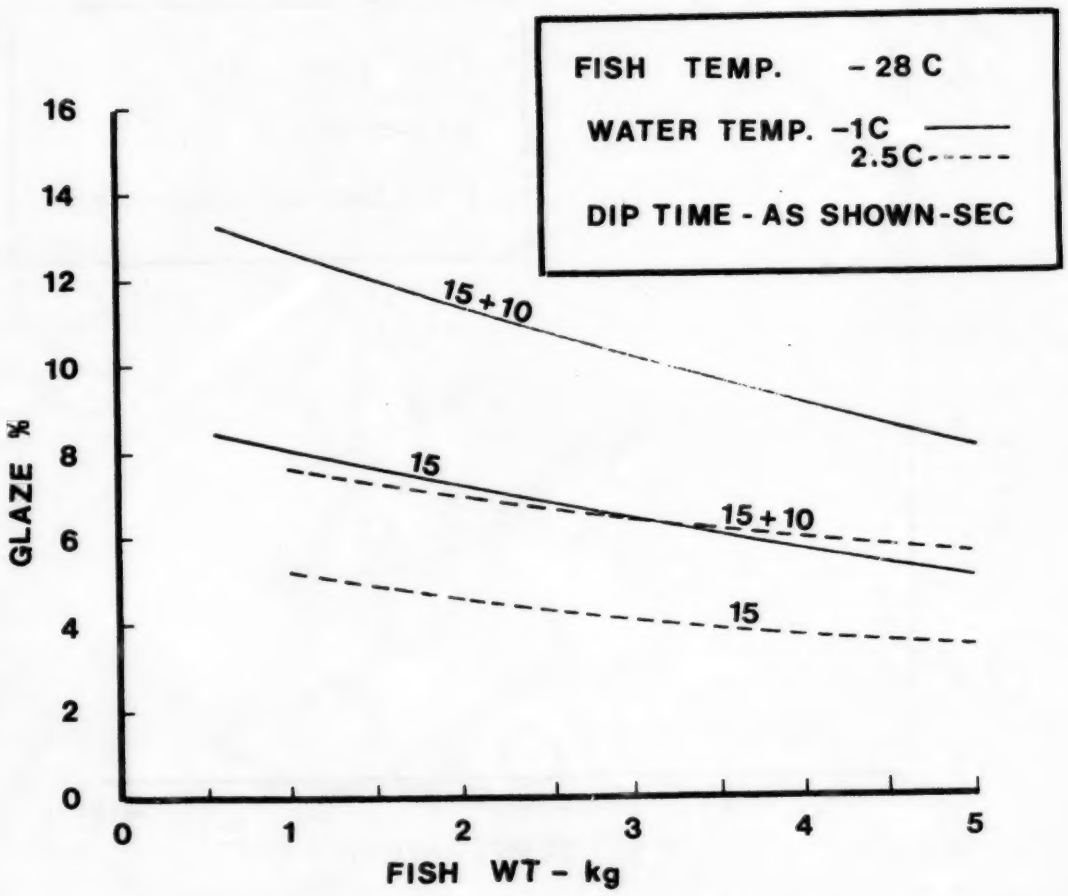


Figure 20. Comparison of glaze % picked up at -1°C and 2.5°C water temp., fish temp. -28°C.

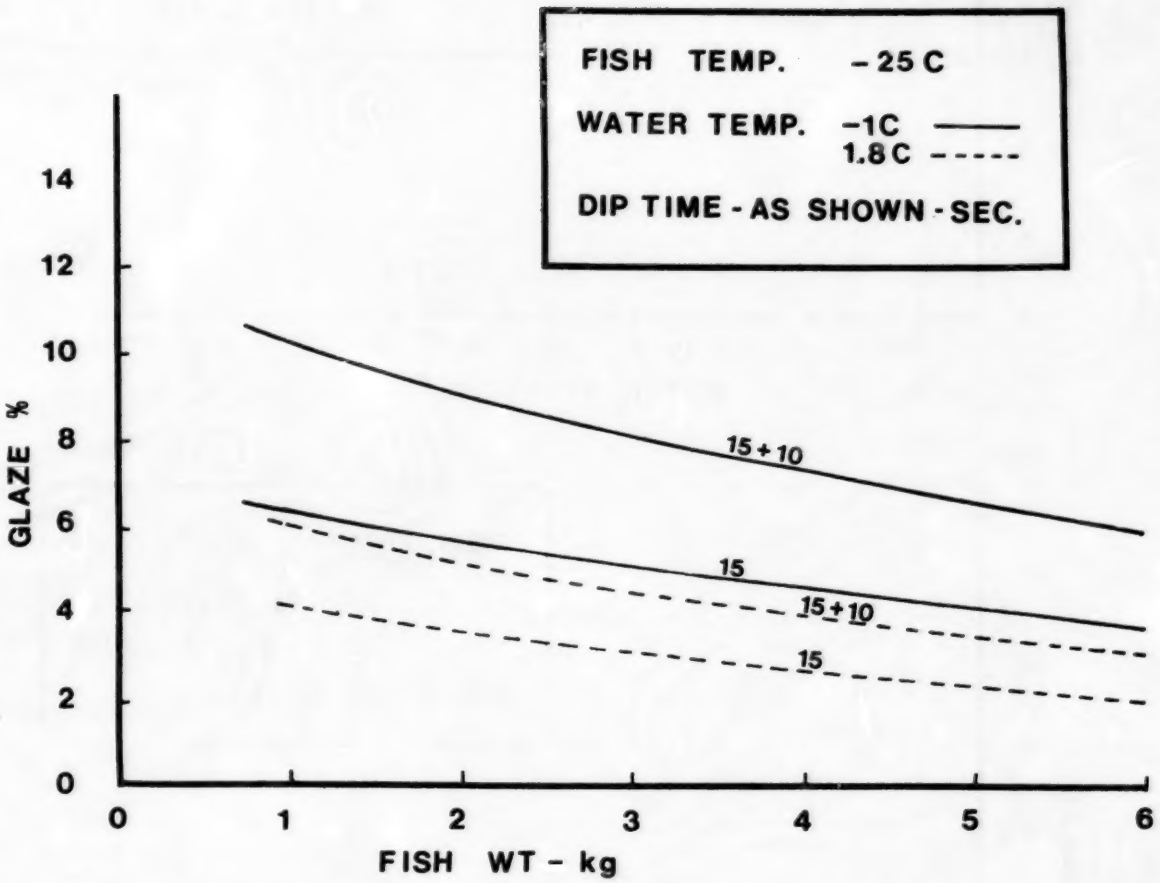
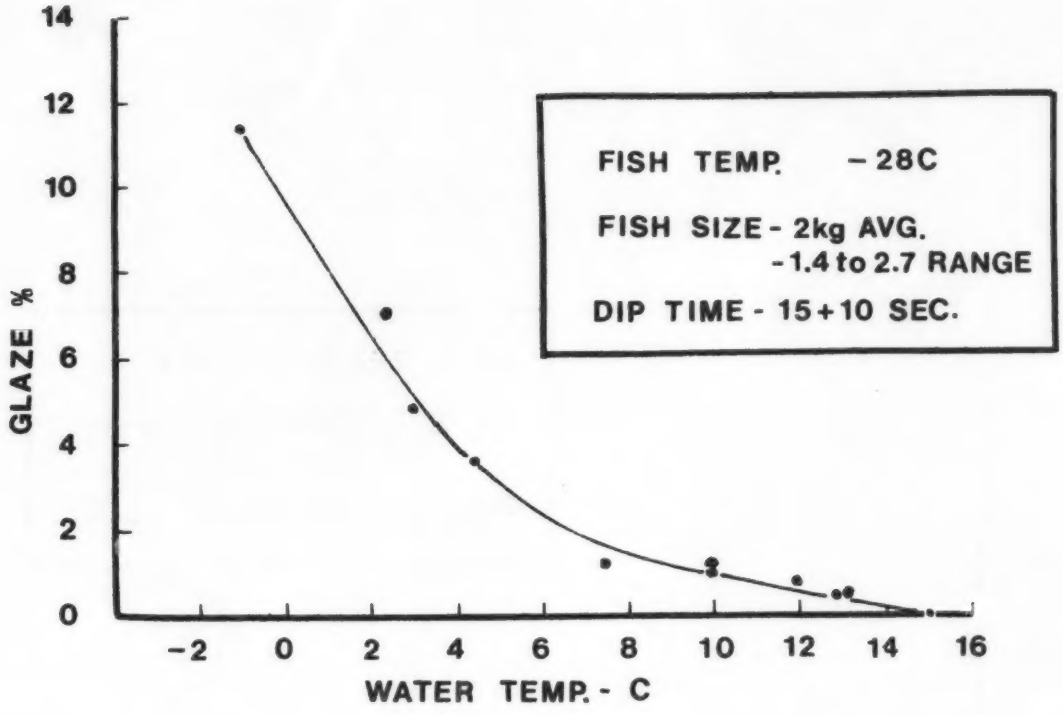


Figure 21. Comparison of glaze % picked up at -1°C and 1.8°C water temp., fish temp. -25°C.



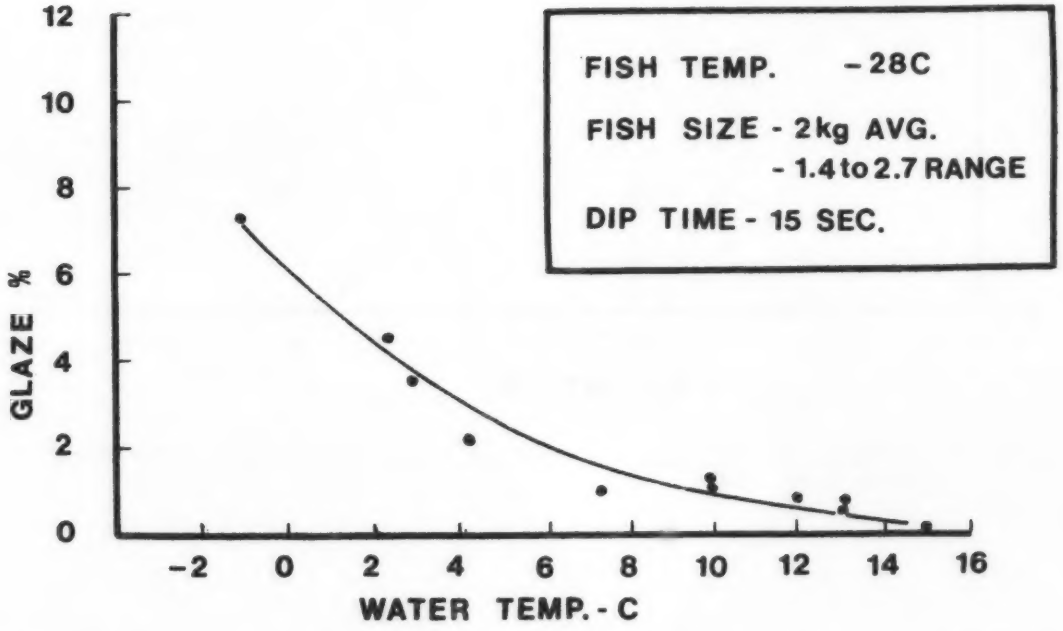


Figure 22. Variation of glaze % with water temp. for 15 and 15 + 10 sec. dip times.

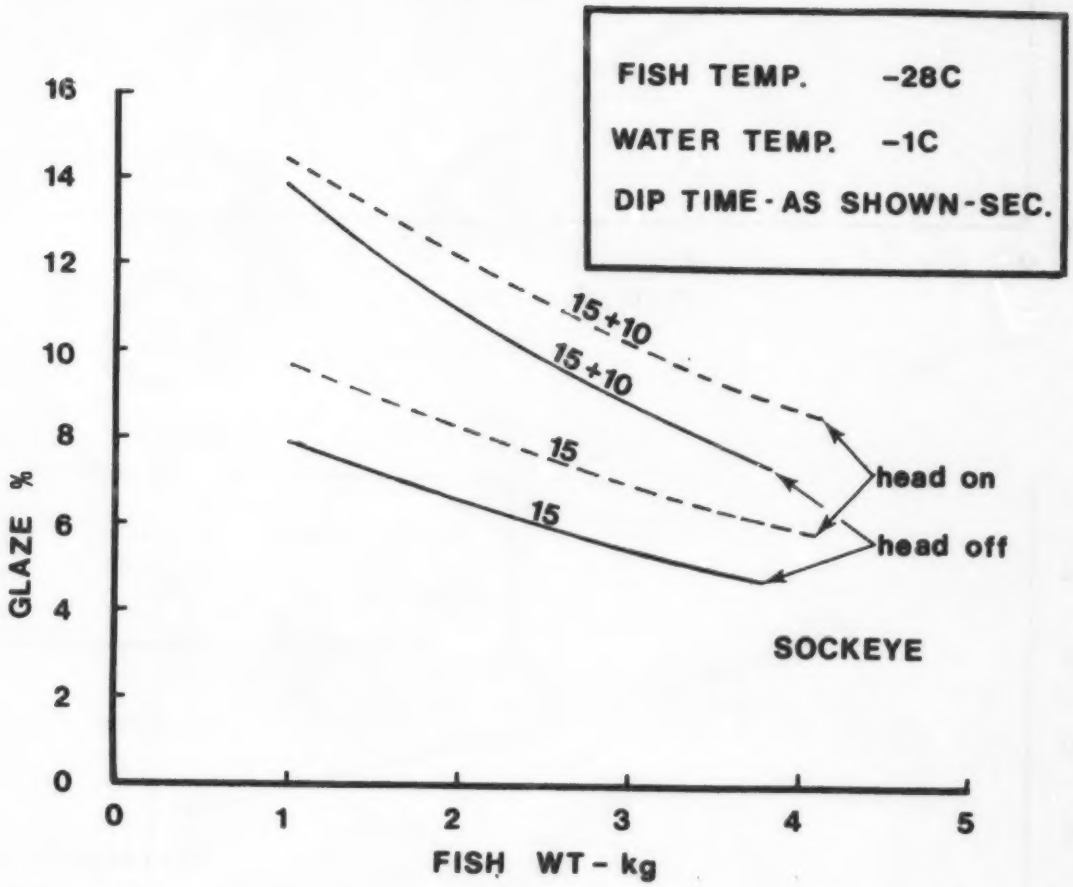


Figure 23. Comparison of glazing head-on and head-off sockeye.

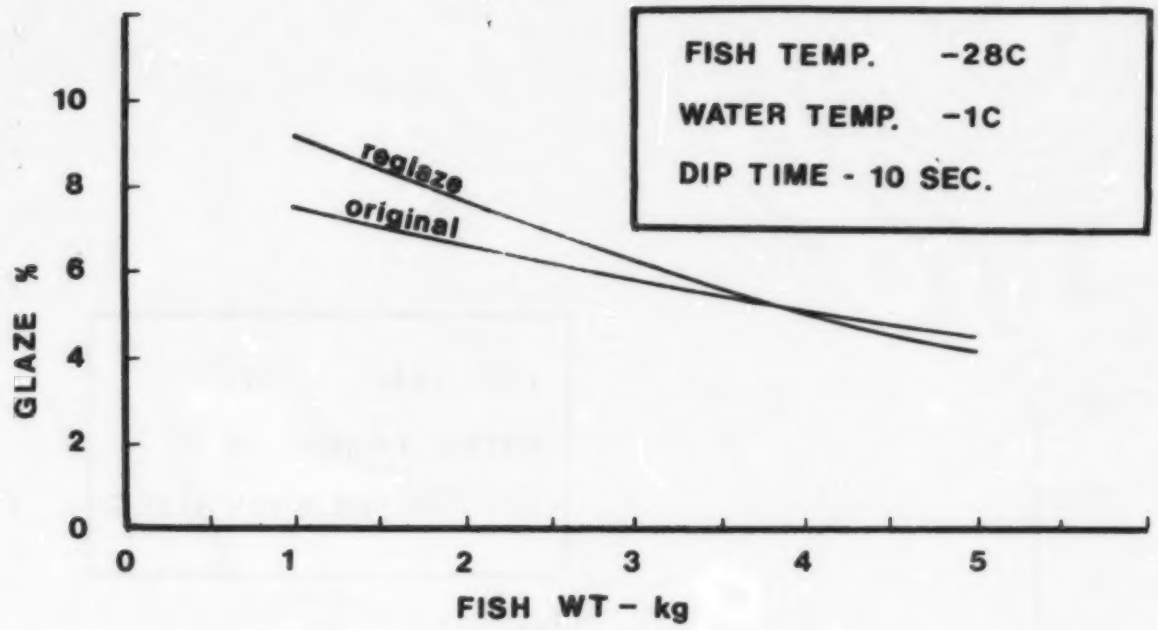


Figure 24. Comparison of original glaze % with reglazing.

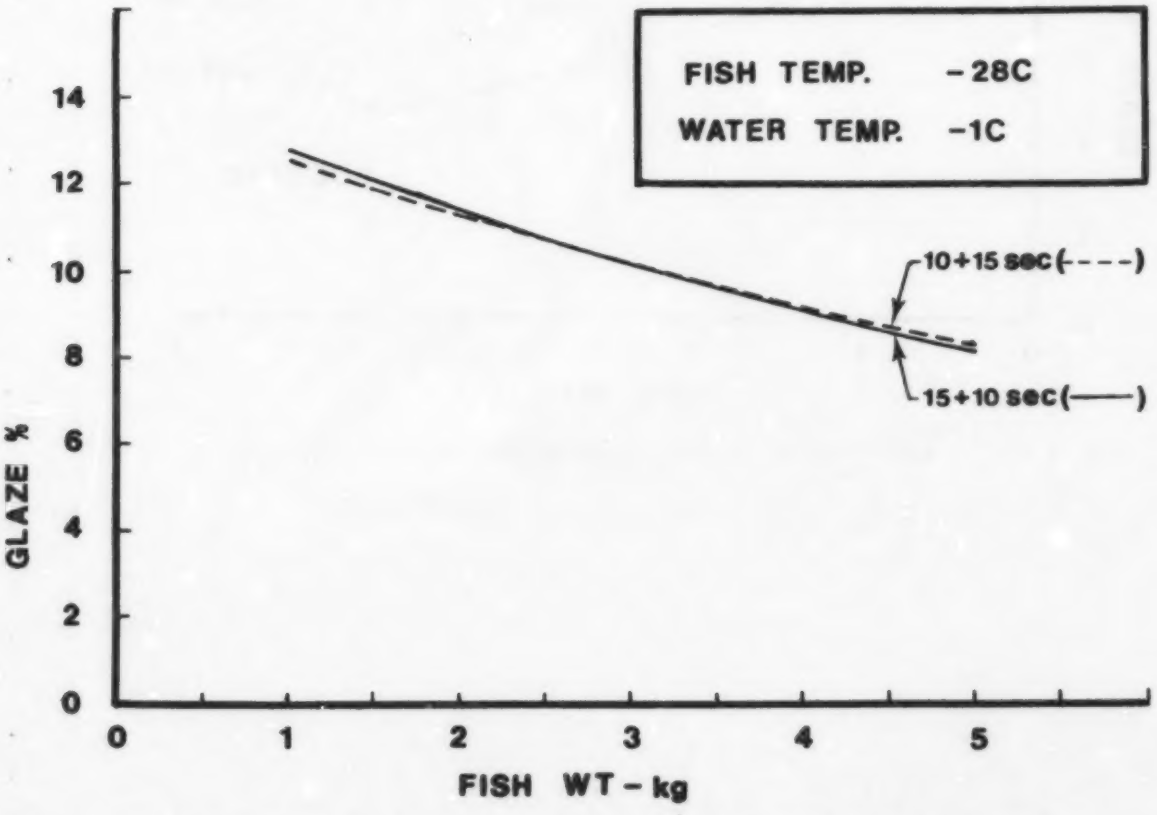


Figure 25. Comparison of 15 + 10 sec. and 10 + 15 sec. dipping sequences.

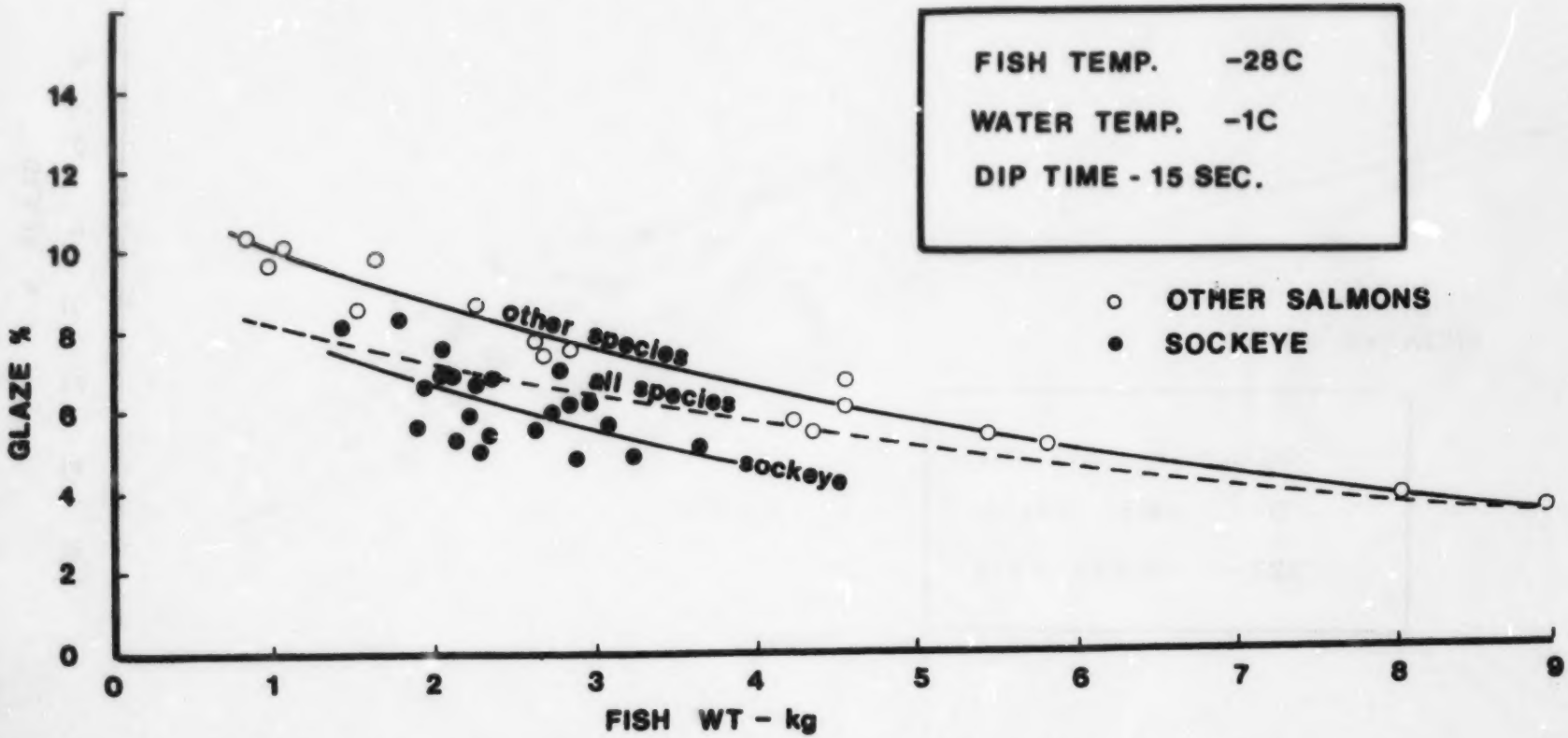


Figure 26. Comparison of glaze % picked up by sockeye and other species at 15 sec. dip time.

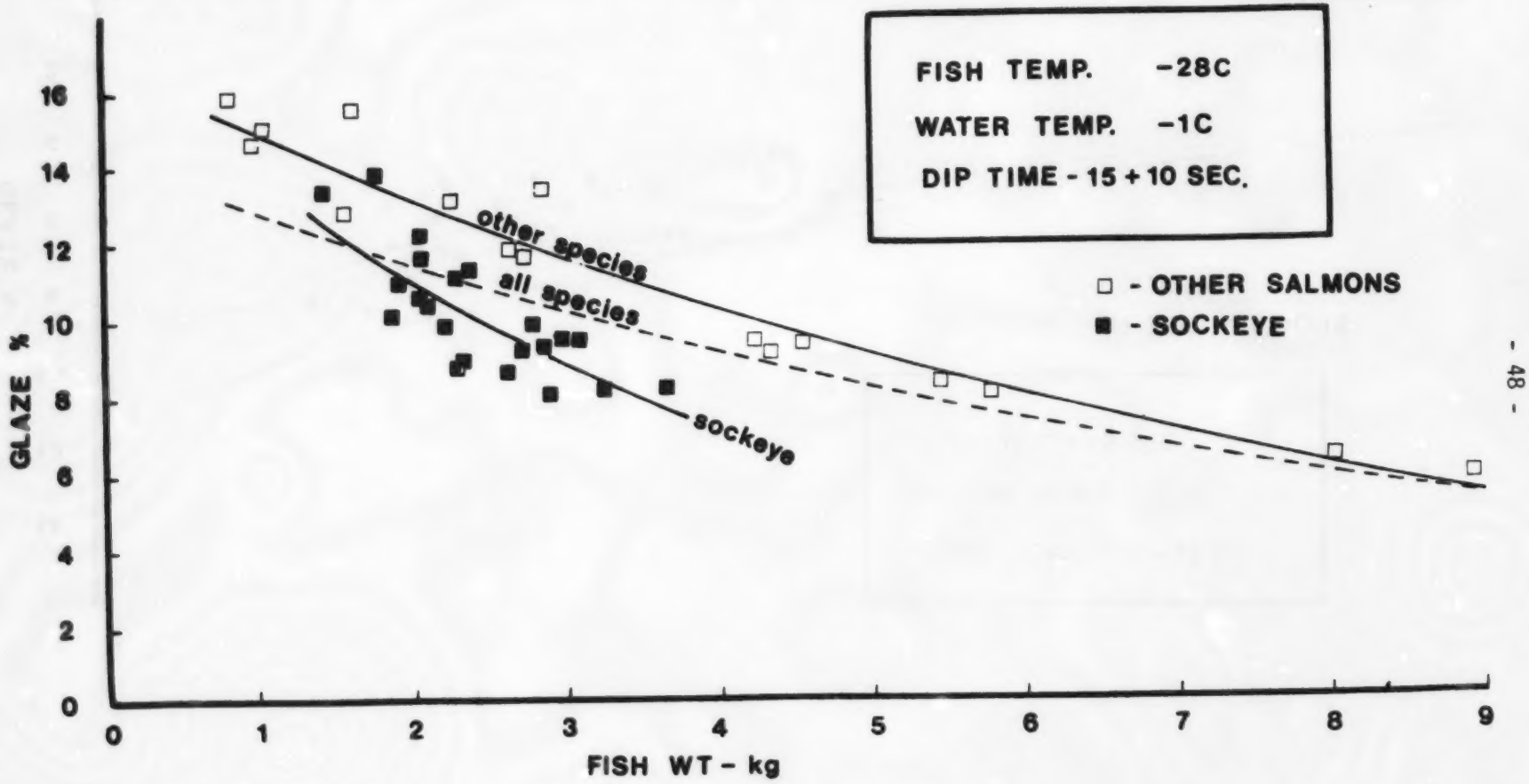


Figure 27. Comparison of glaze % picked up by sockeye and other species at 15 + 10 sec. dip time.

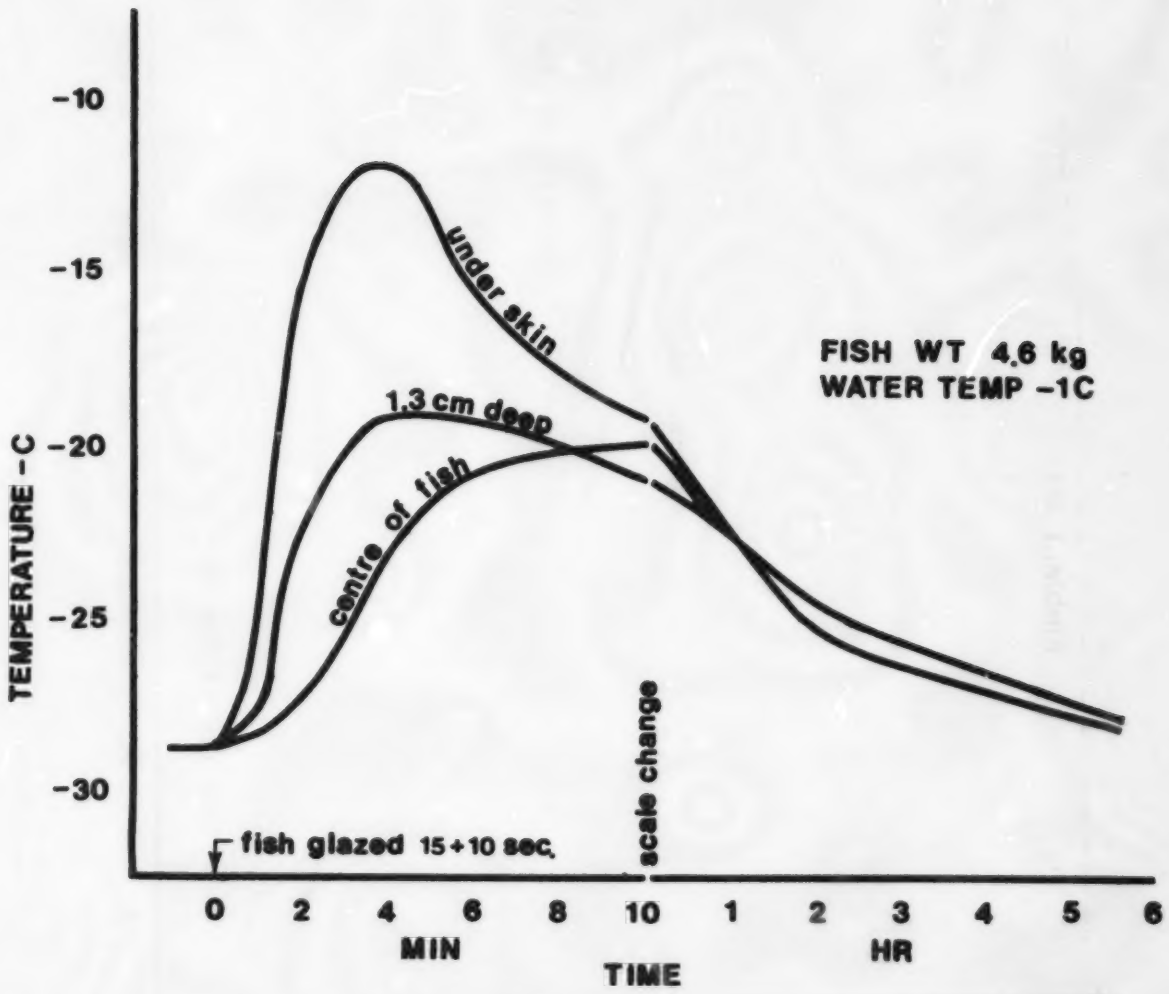


Figure 28. Temperature variation in salmon during the glazing process.

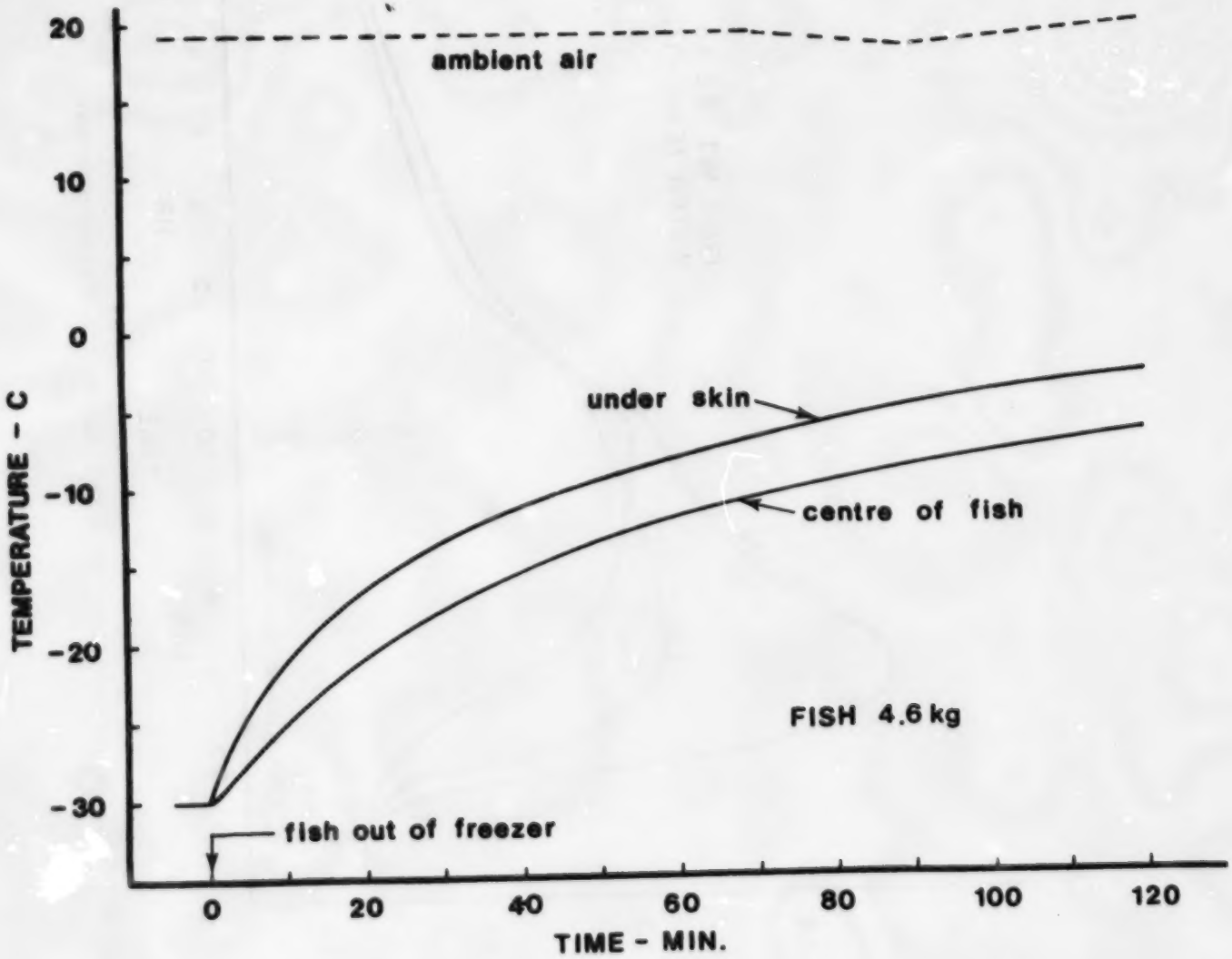


Figure 29. Rate of temperature rise in salmon when removed from freezer.

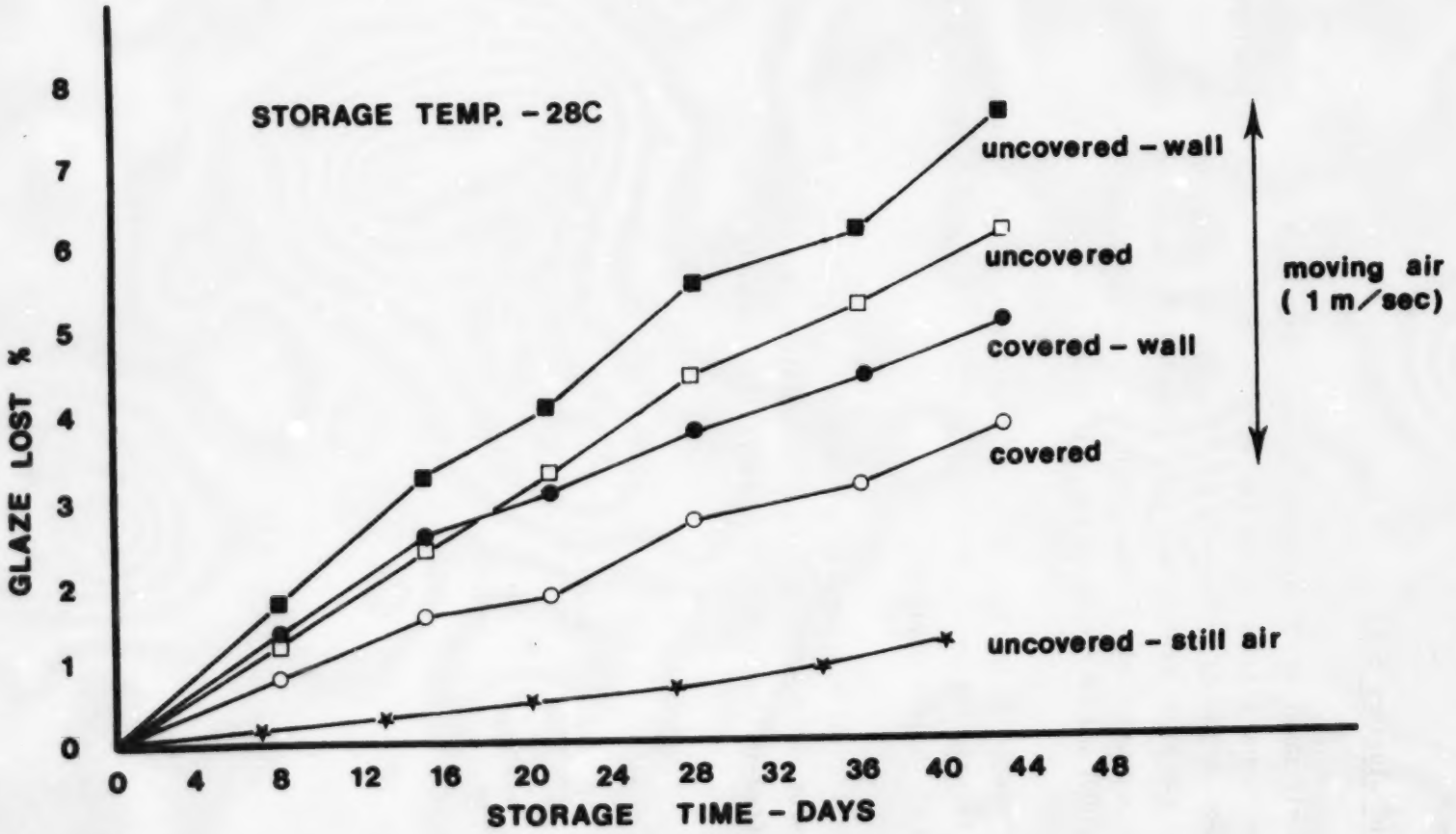


Figure 30. Rate of loss of glaze from salmon in frozen storage.

APPENDIX

Glazing of albacore tuna

A small sampling of albacore tuna was obtained from a freezer vessel and measurements and glazing procedures similar to those previously described for salmon were performed. The fish had been frozen at sea in a combination plate and air-blast freezer and held under still air storage conditions at -28°C for approximately 3 weeks before they were glazed. The fork length and maximum width and thickness of these fish are shown in Figure A1.

For reference, fourteen of these fish were thawed and then gutted and headed. By weighing before and after gutting a yield of 0.79 with a standard deviation of .02 was obtained.

Seven fish over a range of sizes from 2.7 to 10.9 kg were glazed at a fish temperature of -28°C and water temperature of -1°C. The results are shown plotted in Figure A2. The statistical parameters for this data were as follows.

Dip time	Coeff. r	S_G	"t" test level
15	-0.92	.07	<1%
15 + 10	-0.98	.04	<0.1%

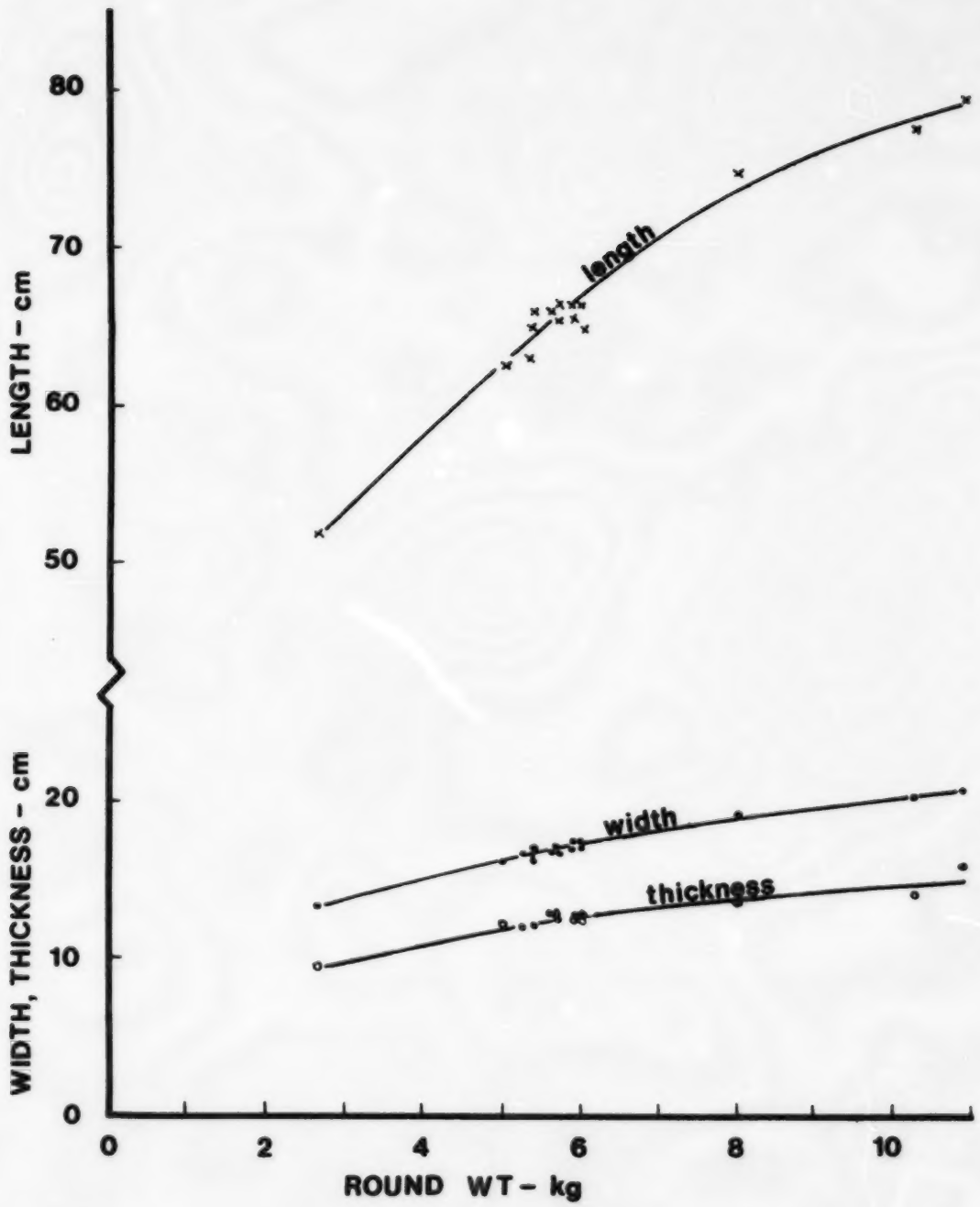


Figure A-1. Weight/size relationships for albacore tuna.

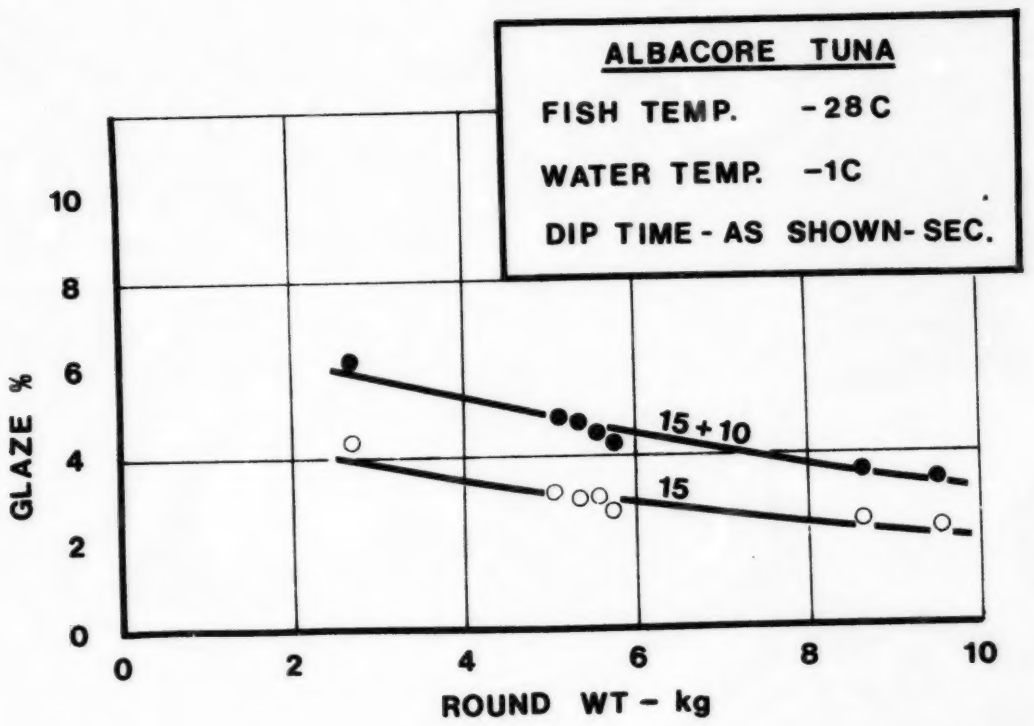


Figure A-2. Glaze %/fish wt for albacore tuna.

POOR

QUALITY

ORIGINAL